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TECHNICAL REPORT REMR-EM-5

LUBRICANTS FOR HYDRAULIC STRUCTURES

by

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The U.S. Army Corps of Engineers constructs and maintains a multitude of Civil Works hydraulic structures. Uniform guidance regarding the specification and use of lubricants for these structures is not currently available. This research determined lubrication practices and problems by surveying all Corps installations having hydraulic structures. Equipment manufacturers and lubricant producers were contacted to obtain state-of-the-art information to help installations determine and obtain appropriate lubricants.

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PREFACE

This study was authorized by Headquarters, US Army Corps of Engineers (HQUSACE), under Civil Works Research Work Unit 32334, "Compatibility of Insulating and Lubricating Oils," for which Mr. Alfred D. Beitelman is Principal Investigator. Funds for testing, compilation of the data, and preparation of this report were provided through the Electrical and Mechanical Problem Area of the Repair, Evaluation, Maintenance, and Rehabilitation (REMR) Research Program, for which Mr. Robert Pletka, CECW-EE, is Technical Monitor.

Mr. Jesse A. Pfeiffer, Jr., (CERD-C) is the REMR Coordinator of the Directorate of Research and Development, HQUSACE; Mr. Jim Crews (CECW-OO), Mr. Bruce L. McCartney (CEEC-EH), and Dr. Tony C. Liu (CEEC-ED) serve as the REMR Overview Committee; Mr. William F. McCleese (WESSC-A) is the REMR Program Manager; Mr. Paul Howdyshell was the Problem Area Leader when this study was accomplished; Mr. Ashok Kumar is the current Problem Area Leader.

This work was conducted by Mr. Ward Clifton of the Bureau of Reclamation for the US Army Construction Engineering Research Laboratory (USACERL) under the general supervision of Dr. R. Quattrone, Chief, Engineering and Materials (EM) Division. The Technical Editor was Gloria J. Wienke, Information Management Office.

COL Norman C. Hintz was Commander and Director of USACERL during this research and Dr. L. R. Shaffer was Technical Director.

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LUBRICANTS FOR HYDRAULIC STRUCTURES

PART I: INTRODUCTION

Background

1. US Army Corps of Engineers field installations continually ask questions about lubricants for Civil Works hydraulic structures. Uniform guidance regarding the specification and use of lubricating oils and greases is not available. Several districts indicate poor performance of given lubricants and concern about the compatibility of alternate lubricants. Synthetic lubricants are being marketed more extensively in recent years and Corps installations are questioning the advisability of switching to more expensive synthetic lubricants. In response to these concerns, a program was developed to provide guidance for lubricating Corps hydraulic structures.

Objective

2. The objective of the work was to determine the Corps' lubrication practices and problems in the areas of lubricating oils and greases and insulating oils, and provide guidance to meet the needs.

Approach

3. Phase I of the program was directed toward learning what lubricants were being used by the Corps and what type of equipment was being lubricated. To accomplish this, a survey was sent to all Corps installations having hydraulic structures. The survey requested that installations supply photocopies of the two engineering forms (ENG 2468 and ENG 2469) required by the Project Operation Maintenance Guide, ER 1130-2-303. Information on any onsite lubricant evaluations or test programs which may have been conducted by the installation as well as point of contact for further coordination was also requested.

4. Phase II consisted of (1) reviewing the survey responses regarding the type of lubricants used and the machinery lubricated, (2) contacting

equipment manufacturers and lubricant producers regarding lubrication needs, providing state-of-the-art information to aid field installations in obtaining appropriate lubricants, and (3) addressing any specific problems indicated by the responses to the survey.

Scope

5. Motor oils are not considered and maintenance procedures are not discussed. General discussions on the nature and production of lubricants are given only for background knowledge to assist in lubricant selection. Since these subjects cover an extensive array of knowledge, only those points useful in lubricant selection are given. Detailed information and instructions for product selection are provided.

PART II: LUBRICATION PRINCIPLES

Friction

6. Friction is the resistance to relative motion between two surfaces in contact. Two general cases occur: sliding friction and rolling friction.

7. Sliding friction is best demonstrated by imagining a brick on a flat surface (Figure 1). If force is applied horizontally, the brick will not move until the force is great enough to set it in motion. This force is equal to the resistance at the instant motion begins and is called the frictional force.

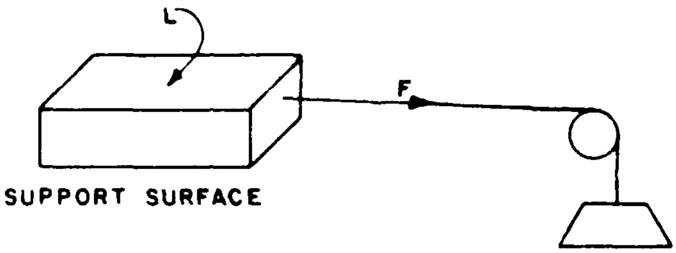

Figure 1. Force F acting on a body with load L

8. Three laws govern the relation between the frictional force and the load or weight (L) of the sliding object. The first law says that the ratio F/L remains constant and is independent of contact area. No matter which face of the brick in Figure 1 is in contact with the surface, the ratio F/L remains the same. The ratio F/L is called the coefficient of friction and may be symbolized $f = F/L$.

9. A second law states F is proportional to L. If two objects of equal weight are placed one above the other on a flat surface to double the weight, the force required to move the combined load would also be doubled. This means that f, the coefficient of friction, remains constant and is independent of load.

10. A third law states that the force required to keep a body in motion is the same regardless of the speed. In other words, F is independent of speed and the coefficient of friction is also independent of speed. The third law implies that the force required to put the body in motion is the same as the force required to keep it in motion. This is not true. Once in motion, the force required to maintain motion is less than the force required to initiate motion. However, once in motion, there is some dependency on velocity. These facts lead to two categories of friction. Static friction is the force required to initiate motion (F_s) and kinetic or dynamic friction is the force required to maintain motion (F_k).

11. The coefficient of friction depends on the type of material. The coefficient for copper is different from that of a bearing alloy or steel. However, it is less dependent on the roughness of the contacting surfaces than one might imagine. Regardless of how smooth a surface may appear, it is composed of small irregularities or asperities. Early researchers supposed that dragging the contacting points of one surface up and over those of another surface constituted the frictional force. (In Figure 2, a force is required to drag point A over point B.) In cases where a surface is extremely rough, the contacting points do play a role, but when the surface is fairly smooth, the points have a very modest effect.

12. However, real surface area is much more important than apparent smoothness. Real or true surface area refers to the area of the points that are in contact with one another. This area is much less than the apparent geometric area. Figure 3 illustrates this relationship. Points A, B, C, and D represent the true area of contact.

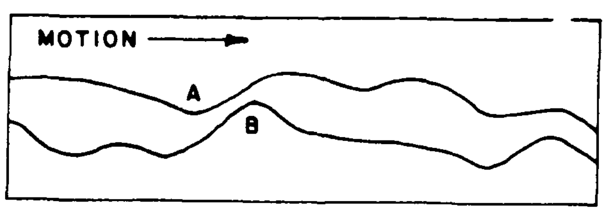

Figure 2. Section of a sliding surface

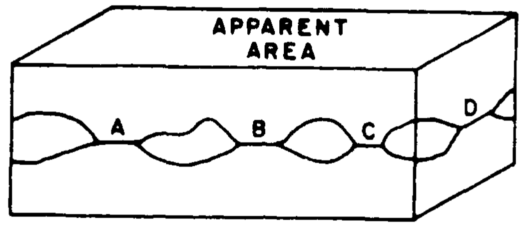

Figure 3. True surface area at points A, B, C and D

13. Adhesion, which occurs at the points of contact, is also more important than apparent smoothness. The term adhesion, as used here, refers to the welding effect that occurs when two bodies are compressed against each other and is more commonly referred to as cold welding. It arises from pressure rather than heat which is associated with welding in the more familiar sense. A shearing force is required to separate the bonded surfaces.

14. The objective of lubrication is to reduce friction by introducing a material with a low shear strength or coefficient of friction between the wearing surfaces. Nature provides such materials in the form of oxides and other contaminants but the reduction in friction due to their presence is insufficient for machinery operation. However, the coefficient of friction is much lower than it would be for clean metal.

15. In such cases, a second relationship is often used to define the coefficient of friction: $f = S/P$, where S is the shear strength of the material and P is pressure (or force) contributing to compression. From this relationship, it is apparent that the coefficient of friction is a function of the force required to shear a material.

16. Sliding motion appears to be smooth but is actually jerky or intermittent because the object slows during shear periods and accelerates following the shear. After acceleration, another set of shearing obstacles are met and the process is repeated. During shear periods, F_s controls the speed. Once shearing is completed, F_k controls the speed and the object accelerates. In well-lubricated machinery operated at the proper speed, this effect is

insignificant. However, under special circumstances, this motion is responsible for the squeaking or chatter sometimes heard in machine operation. Machines that operate over long sliding surfaces, such as the ways of a lathe, are subject to this effect which is referred to as "stick-slip." Lubricants with additives to make F_k greater than F_s are used to overcome this effect.

17. Rolling friction is also important. Experience shows that much less force is required to roll an object than to slide or drag it. Nonetheless, force is required to initiate and maintain rolling motion. Consequently, there must be a definite although small amount of friction involved. The precise manner in which rolling friction occurs is beyond the scope of this work. However, the following generalizations will help to understand rolling friction.

18. Theoretically, a rolling sphere or cylinder should make contact with a flat surface at a single point or along a line (in the case of a cylinder). In reality, the area of contact is slightly larger than a point or line and is formed by elastic deformation of either the rolling object or the flat surface, or both. Much of the friction is attributed to elastic hysteresis. If an object were perfectly elastic, it would spring back immediately after relaxation of the deformation, but this is not usually the case. A small but definite amount of time is required to restore the original shape. As a result, energy is not entirely returned to the object or surface. It is retained and converted to heat. The force which supplies that energy is, in part, the rolling frictional force.

19. A certain amount of slippage (which is the equivalent of sliding friction) is involved in rolling friction. If the friction of an unhoused rolling object is measured, slippage plays only a very small part. However, in practical applications such as a housed ball or roller bearing, some slippage occurs and contributes to rolling friction. Disregarding slippage, rolling friction is very small compared to sliding friction.

20. Although laws for sliding friction cannot be applied to rolling bodies in equally quantitative terms, the following generalities can be given:

- a. The frictional force can be expressed as a fractional power of the load times a constant ($F = kL^x$) but the constant (k) and the power (x) must be determined experimentally.

b. The frictional force is an inverse function of the radius of curvature. As the radius increases, the frictional force decreases.

c. The frictional force decreases as the smoothness of the rolling element improves.

d. The static frictional force (F_s) is much greater than the kinetic force (F_k).

Wear

21. Friction creates heat and causes wear. Because heat generation due to friction is so common, it will not be discussed here. However, wear deserves some consideration.

22. Wear removes material from working surfaces. Although it is an inescapable process, it can be reduced by appropriate machinery design, precision machining, proper maintenance, and proper lubrication. Ordinarily, wear is thought of only in terms of abrasive wear occurring in connection with sliding motion and friction. However, wear can also be the result of adhesion, corrosion, or fatigue.

23. Abrasive wear occurs when one wearing surface cuts into and plows out a small portion of the other. Dust and dirt between wearing surfaces contribute to abrasive wear.

24. Adhesive wear occurs when points of contact (which constitute the true area of wear) undergo adhesion. Although shearing often occurs along the plane where adhesion took place, it also occurs as shown in Figure 4.

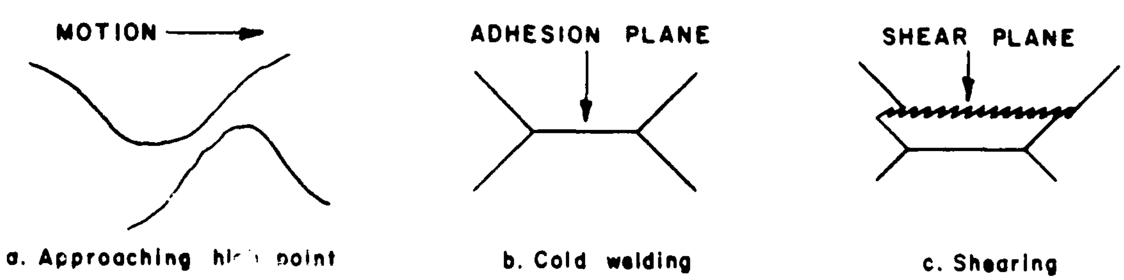

Figure 4. Shearing of a welded junction

Presumably, shearing occurs through the weakest section, which is not necessarily at the adhesion plane. In many cases, shearing occurs in the softer material, but such a comparison is based on shear tests of relatively large pure samples. The adhesion junctions, on the other hand, are very small spots of weakness or impurity that would be insignificant in a large specimen but in practice may be sufficient to permit shearing through the harder material. Investigations have shown that both faces of wearing surfaces of different hardness contain traces of material from the other face (Bowden 1967)*. Theoretically, this type of wear does not remove material but merely transfers it between wearing surfaces. However, the transferred material is often loosely deposited and eventually flakes away in microscopic particles.

25. Corrosive wear occurs when a chemical reaction occurs on either wearing surface. The most common form of corrosion is due to a reaction between the metal and oxygen, but other chemicals could be responsible if present. Corrosion products (usually oxides) have shear strengths that differ from those of the metals of the wearing surfaces from which they were formed. They tend to flake away, resulting in pitting of wearing surfaces. Ball and roller bearings depend on extremely smooth surfaces to reduce frictional effects. Corrosive pitting is especially detrimental to these bearings.

26. Metal fatigue is demonstrated by bending a piece of metal wire back and forth until it breaks. Whenever a metal shape is deformed many times, it eventually fails. A different type of deformation occurs when a ball bearing under a load rolls along its race. The bearing is flattened somewhat and the edges of contact are extended outward. This repeated flexing eventually results in microscopic flakes being removed from the bearing. Fatigue wear also occurs during sliding motion.

27. Not all wear is considered detrimental. During the break-in period of new machinery, friction wears down working surface irregularities and redistributes the material.

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*Bowden, F.P. 1967. Friction and Lubrication, Methuen and Co., London.

Viscosity

28. Viscosity is a property of fluids. It is defined as shear stress divided by shear rate and is regarded as a measure of the resistance to a shearing force. A fluid with high viscosity does not flow easily and requires more force in a given unit of time for shearing. Fluids with low viscosity flow easily and require less force.

29. When viscosity is determined by directly measuring shear stress and shear rate, it is expressed in centipoise (cP) and is referred to as the absolute viscosity or dynamic viscosity.

30. In the oil industry, it is more common to use kinematic viscosity which is the absolute viscosity divided by the density of the oil being tested. Kinematic viscosity is expressed in centistokes (cSt). Viscosity in centistokes is conventionally given at two standard temperatures: 104 and 212° F (40 and 100° C).

31. In many cases, the viscosity of an oil is not determined by measuring shear stress and shear rate directly. Instead, the time required for an oil to flow through a standard orifice at a standard temperature is used. Viscosity is then expressed in SUS (Saybolt Universal Seconds). SUS viscosities are also conventionally given at two standard temperatures: 100 and 210° F (37 and 98° C).

32. Professional societies classify oils by viscosity ranges or grades. The most common systems are those of the SAE (Society of Automotive Engineers), the AGMA (American Gear Manufacturers Association), the ISO (International Standards Organization), and the ASTM (American Society for Testing and Materials). Other systems are used in special circumstances.

33. This variety of grading systems can be confusing. A specification giving the type of oil to be used might identify an oil in terms of its AGMA grade, for example, but an oil producer may give the viscosity in terms of cSt or SUS. Conversion tables for the various grading systems are given in Appendix A. Conversion between cSt and SUS viscosities at standard temperatures can also be obtained from ASTM D 2161.

34. Ordinarily, fluid lubricants are oils. The viscosity of oil varies inversely with its temperature. As temperature increases, oil viscosity decreases and when temperature decreases, oil viscosity increases. Oils

also vary in the extent to which their viscosity changes with temperatures. For some temperature range, say 0 to 100° F (-18 to 37° C), one oil may change considerably more than another. A measure of this tendency has been devised and is called the viscosity index (VI). The higher the VI, the less the viscosity will change over a given temperature range. The lower the VI, the more the viscosity will change. An oil with a VI of 95 to 100 would change less than one with a VI of 80. Proper selection of petroleum stocks and additives can produce oils with a very good VI (see Part III).

Objectives in Lubrication

35. The fundamental principle of lubrication is to interject a material with a lower shear strength (or coefficient of friction) between wearing surfaces that have a relatively high coefficient of friction. In effect, the wearing surfaces are replaced by a material with a more desirable coefficient of friction. A material used to reduce friction in this way is a lubricant. Liquids, solids, and even gases can be used as lubricants. Industrial machinery ordinarily uses oil or grease, but solid additives such as molybdenum disulfide or graphite may be included when loading is heavy. In special cases, wearing surfaces are plated with a different metal to reduce friction.

36. The ultimate goal of lubrication is to reduce heat and wear to negligible or acceptable levels. Since both heat and wear are associated with friction, they can be reduced by reducing the coefficient of friction. Lubricants may also be used to reduce oxidation and prevent rust. However, all such functions ultimately contribute to reducing heat and wear.

Hydrodynamic Lubrication

37. In hydrodynamic lubrication, wearing surfaces are completely separated by a film of oil. A good example of this type of lubrication is provided by a loaded plate riding on a flat surface (Figure 5). Before motion takes place, the loaded plate rests on the supporting surface. As the plate is put in motion, it meets a certain amount of resistance or opposing force due to viscosity of the oil. This causes the leading edge to

Figure 5. Hydrodynamic lubrication.

lift slightly and allow a small amount of oil to come between the plate and supporting surface. As velocity increases, the wedge-shaped oil film increases in thickness until constant velocity is attained. A similar phenomenon is witnessed when someone water skies. When the velocity is constant, oil entering under the front edge equals the amount passing outward from the trailing edge. For the loaded plate to remain above the supporting surface there must be an upward pressure that equals the load. Large thrust bearings, such as those found in generators at hydroelectric plants, operate under this principle. However, the design must allow the plates to lift and tilt properly and provide sufficient area to lift the load.

38. Another example of hydrodynamic lubrication is found in operation of journal or sleeve bearings and is depicted, with exaggerated dimensions, in Figure 6. Before motion begins, the journal rests on the bearing centered on the vertical diameter. When the journal rotates, oil adhering to the journal causes a buildup of pressure indicated by the shaded area on Figure 6a. As the velocity of rotation increases, this pressure lifts the journal to provide a curved wedge-shaped film that prevents contact between the journal and its bearing. The point of least film depth is not on the vertical diameter; it is shifted to the left as indicated in Figure 6b. Eventually, velocity becomes constant and the journal rides on a film of oil sufficient to prevent contact with the bearing surface.

39. This is a very simplified explanation. A more precise mathematical theory was developed by Reynolds before the turn of the century and is now referred to as the Reynolds equation. It is a rather complicated analysis and more simplified equations have been developed to provide equivalent approximations. From such equations, film thickness may be calculated with a considerable degree of precision.

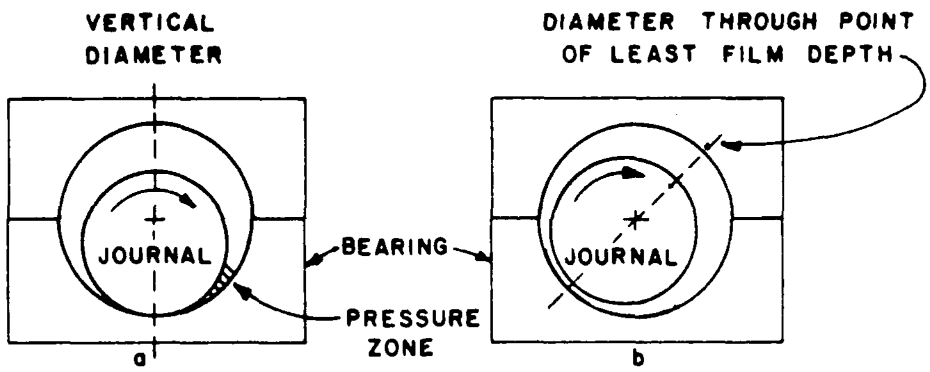


Figure 6. Hydrodynamic lubrication of a journal bearing

40. Regardless of how film thickness is calculated, it is a function of viscosity, velocity, and load. As viscosity or velocity increases, the film thickness increases. When these two variables decrease, the film thickness also decreases. Film thickness varies inversely with the load. As the load increases, film thickness decreases. Viscosity, velocity, and operating temperature are also interrelated. If viscosity is increased, the operating temperature will increase, which has a tendency to reduce viscosity. Thus, and increase in viscosity tends to neutralize itself somewhat. Velocity increases also cause temperature increases accompanied by a viscosity reduction.

41. Theoretically, hydrodynamic lubrication reduces wear to zero. In reality, the journal tends to move due to load changes or other disturbances and some wear does occur. Nonetheless, hydrodynamic lubrication reduces sliding friction and wear to a minimum.

Boundary Lubrication

42. Lubrication designed to protect against frictional effects when asperities meet is called boundary lubrication. Materials contained in the lubricant attach themselves to the wearing surfaces and lower the coefficients of friction.

43. In the past, animal fats and vegetable oils were used as boundary lubrication. When petroleum began to provide lubricating oils, it was found that if fat was added to mineral oil the resulting compound could reduce the coefficient of friction between wearing surfaces even though the viscosity was the same as for untreated mineral oil. This quality of lowering the coefficient of friction for a given viscosity is known as oiliness or lubricity and arises from the presence of long-chain fatty acids.

44. Long-chain fatty acids are composed of a chain of carbon atoms that has oxygen at one end of the molecule, making the molecule polar and reactive. Although Part III gives more detail on the nature of these molecules, the following is sufficient to describe what takes place.

45. The fatty molecules attach themselves to metal surfaces by either of two mechanisms. In the first case, the molecules adhere to a metal surface due to their polar nature. Mineral oil would also adhere to a metal surface; however, the adherence is much weaker than that of the fatty acids. This type of attachment is referred to as adsorption. Fatty molecules dissolved in the oil attach themselves to a metal surface by their polar ends in an array similar to the hairs of a brush (Figure 7). Remember that the surface is not truly metallic, but a microscopic coating of oxides and impurities. The surfaces slide over these molecules which provide a reduced coefficient of friction and reduced heating and wear. However, adsorption is a reversible process. If the temperature is raised to the melting point of the fatty acids, they will be removed from the surface and go back into solution with

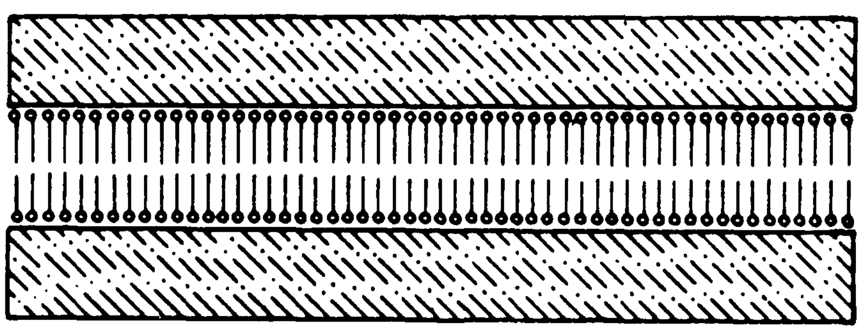


Figure 7. Adsorption of fatty acids on wearing surfaces

the oil. The adsorbed molecules may also be removed by physical force if contact between asperities is too severe.

46. The second mechanism of attachment is called chemisorption. In this process, the fatty acids react with the true metal surface and form a bond, which is somewhat stronger than that of adsorption, and a new chemical--a soap. Due to the stronger bonding, a greater degree of protection is provided. This type of bonding is irreversible. The soap does not become detached when the temperature reaches the soap's melting point. Detachment does not occur until a temperature considerably above the melting point is reached. Higher temperatures and severe contact will, in the end, remove the soap and put it in solution. (See Part III for a description of soaps.)

47. Chemicals that provide protection in this manner are called antiwear agents and oils that have been treated with them are classed as AW (antiwear). Most oils intended for use in heavier machine applications contain antiwear agents. However, AW agents are effective only up to a maximum temperature of about 250° C (480° F).

EP Lubrication

48. Because heavy loading causes the temperature to increase, antiwear protection is effective only up to some limit of loading and the associated temperature. When pressure becomes too great, asperities make contact with greater force. Instead of sliding, shearing takes place, removing the lubricant and the oxide coating. Under these conditions (Figure 8), the coefficient of friction is greatly increased and the temperature reaches a damaging level.

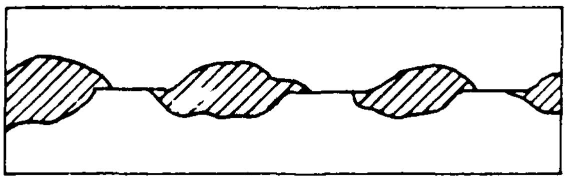


Figure 8. Wearing surfaces shear when a lubricant fails under extreme pressure

49. Lubricants that protect against extreme pressure are called EP lubricants and oils containing additives to protect against extreme pressure are classified as EP oils. EP lubrication is provided by a number of chemical compounds. The most common are compounds of phosphorous, sulfur, or chlorine. The compounds are activated by the higher temperature resulting from extreme pressure, not by the pressure itself. As the temperature rises, EP molecules become reactive and release phosphorous, chlorine, or sulfur (depending on which compound is used) to react with only the exposed metal surfaces to form a new compound such as iron chloride or iron sulphide. The new compound forms a protective coating on the exposed metal. Thus, the protection is deposited at exactly the sites where it is needed. Fatty acids in the EP oil continue to provide AW protection at sites where wear and temperature are not high enough to activate the EP agents. Figure 9 gives graphic representation of how EP and AW agents work together.

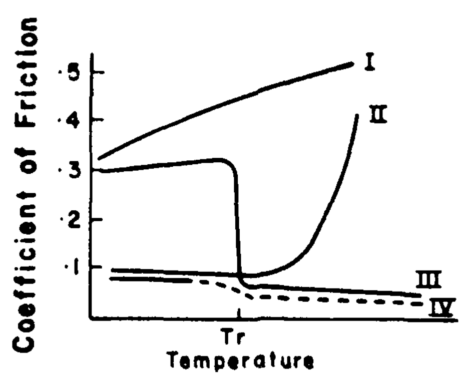


Figure 9. Frictional behavior of metal surfaces lubricated with an oil containing AW and EP agents.
Curve I: paraffin oil; Curve II: fatty acid; Curve III: E.P. lubricant which reacts with the surfaces at temperature Tr; Curve IV: mixture of E.P. lubricant and fatty acid. The fatty acid provides effective lubrication at temperatures below those at which the E.P. additive reacts with the metal.

Elastohydrodynamic Lubrication (EHD)

50. The lubrication of rolling bodies is called elastohydrodynamic lubrication. This cumbersome wording is conventionally shortened to EHD. Lubrication for rolling objects (ball or roller bearings) operates on a considerably different principle than for sliding objects, although the principles of hydrodynamic lubrication explain quite a bit about lubricating rolling elements. Figure 10 shows that a wedge of oil exists at the forward underside of the bearing. In hydrodynamic lubrication, adhesion of oil to the sliding element and the supporting surface increases pressure and creates a film between the two bodies. For rolling elements however, the deformed area of contact is extremely small and the force per unit area, or pressure, is tremendous. In a roller bearing, pressure may reach 5,000 lb/sq in. (34,450 kPa). In a ball bearing, pressure may reach 100,000 lb/sq in. (689,000 kPa). It would seem that the oil would be entirely squeezed from between the wearing surfaces at these pressures. However, viscosity may increase from 100 to 100,000 times under extremely high pressure. This prevents the oil from being entirely squeezed out. Consequently, a thin film of oil is present.

51. The roughness of the wearing surfaces plays an important role in EHD lubrication. Roughness is given as the arithmetic average of the distance from high to low points of a surface. This is sometimes called the centerline average (CLA). This average is not a particularly good measure of roughness because an individual peak to height distance might be as much as 6 to 10 times as large as the CLA. However, no better method has been found to simply express roughness.

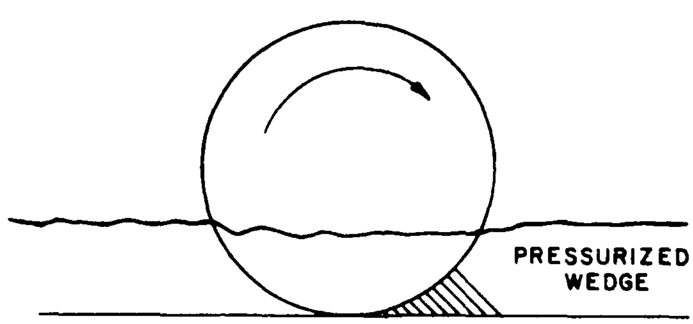


Figure 10. Area of pressure in a rolling body

52. The greater the film thickness in relation to roughness, the less surface asperities will make contact. Engineers use the ratio of film thickness (h) to roughness (CLA) to estimate life of a bearing system. The ratio is symbolized by the greek letter Λ (lambda): $\Lambda = h/CLA$ where CLA is the average of both surface CLAs.

53. Full film thickness is considered to exist when the value of Λ is between two and four. When full film lubrication exists, fatigue failure is due entirely to subsurface stress. However, in most industrial applications, a value of Λ between one and two is achieved and surface stress occurs (i.e., surface asperities undergo stress) and contributes to fatigue. Fatigue is a major source of wear in antifriction bearings.

54. The relation of bearing life to Λ is very complex and not always predictable. However, as a generality, life is extended as Λ increases.

PART III: LUBRICATING OILS AND GREASES

The Nature of Oil

55. Petroleum is a mixture of chemical compounds formed from the remains of ancient animals and plants. It is trapped in porous rock formations and is usually associated with concentrated saltwater. The majority of petroleum belongs to the chemical class called hydrocarbons, which are chains of carbon atoms compounded with hydrogen. The number of carbons may range from 1 (in methane gas) to well above 50. Hydrocarbons are further broken into three classes: paraffins, naphthenes, and aromatics. The carbon atoms in paraffins are aligned in straight or branched chains (Figure 11). Naphthenes are similar to paraffins except that the ends of the molecule are connected to form closed rings (Figure 12). Aromatics also form rings (Figure 13). However, they contain fewer hydrogen atoms due to double bonding between some of the six carbon atoms. Several rings may be fused together.

56. Combinations of these three classes also occur. A paraffin may be connected to a naphthenic ring and through another chain to an aromatic. Furthermore, only the smallest simple molecules have been shown here for the sake of convenience. Petroleum may contain molecules with up to 50 or more carbon atoms, and may contain impurities such as metals or compounds of sulfur, nitrogen, or oxygen.

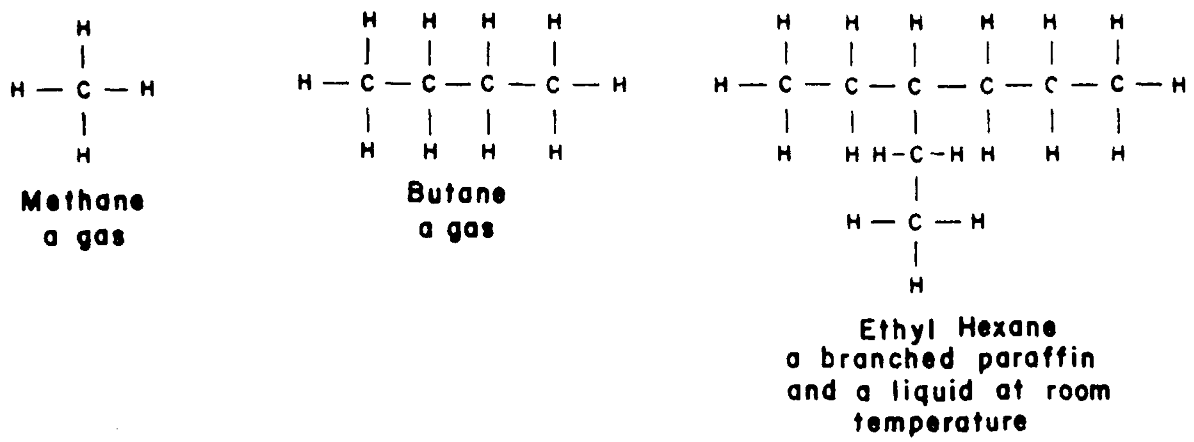
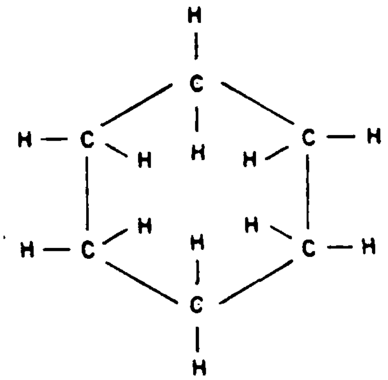
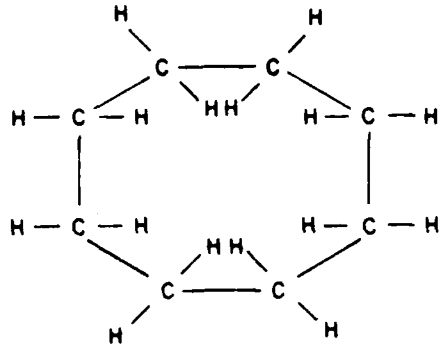


Figure 11. Paraffin structures

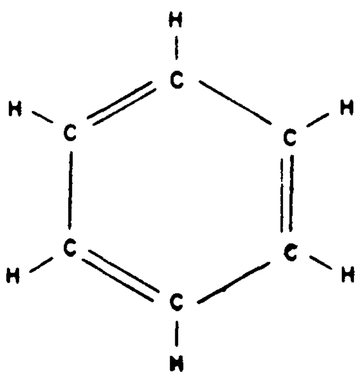


Cyclohexane

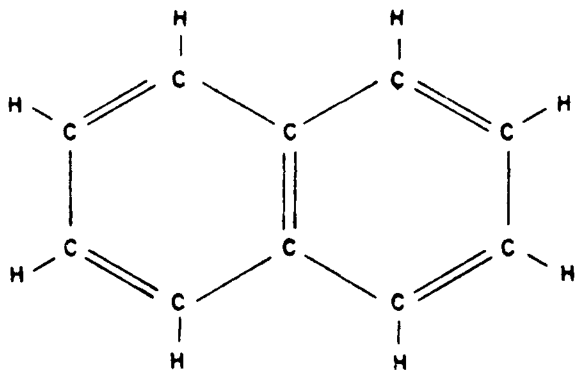


Cyclooctane

Figure 12. Naphthenic structures



Benzene



Naphthene
a fused aromatic

Figure 13. Aromatic structures

57. There is another class of chemical compounds, the fatty acids, which were mentioned in Part II, but could not be adequately described at that point. Some idea of the nature of fatty acids can now be given.

58. Fatty acids are essentially paraffinic chains with a reactive group at one end (Figure 14). This causes the molecule to attach or adsorb itself to metal surfaces more strongly than would be true for a simple paraffin. The chains may contain 15 to 20 carbon atoms.

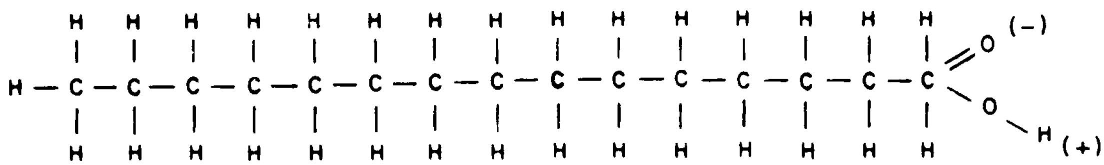


Figure 14. A long-chain fatty acid structure

Oil Refining

59. Due to the wide variety of petroleum constituents, it is necessary to separate petroleum into fractions with roughly the same qualities. This is accomplished by distillation. The crude petroleum is first mixed with water to dissolve any salt. The resulting brine is separated by settling. The remaining oil is pumped through a tubular furnace where it is partially vaporized. The components that have a low number of carbon atoms vaporize and pass into a fractionating column or tower. As the vapors rise in the column, cooling causes condensation. By controlling the temperature, the volatile components may be separated into fractions that fall within particular boiling point ranges. In general, those compounds with the lowest boiling points have the fewest carbon atoms and those with the highest boiling points have the greatest number of carbon atoms. This process reduces the number of compounds within each range and provides different qualities.

60. There are two distinct stages in distillation. The first stage (described in the preceding paragraph) produces raw gasoline, kerosene, and diesel fuel. The second stage involves distilling the portion of the first stage that did not volatilize (the residuum). Lubricating oils are obtained from the residuum.

61. The residuum is distilled under vacuum so it will boil at a lower temperature. If the temperature is too high, undesirable products are obtained. Distillation of the residuum produces oils of several boiling point ranges. Again, the higher the boiling point, the higher the carbon content of

the oil molecules in a given range. More importantly, viscosity also varies with the boiling point and the number of carbon atoms in the oil molecules.

62. This description of refining is, of course, very simplified. Once the oil is separated into fractions, it must be further treated to remove impurities, wax, resins, and asphalt. Those oils that have been highly refined are usually referred to as premium grades to distinguish them from grades of lesser quality in the producer's line of products. However, there is no criteria to establish what constitutes premium grade.

63. A broad general scheme of the refining is as follows:

a. Crudes are segregated and selected depending on the types of hydrocarbons in them.

b. The selected crudes are distilled to produce fractions in the same general boiling point range.

c. Each fraction is processed to remove undesirable components. This may include:

(1) Solvent refining to remove undesirable compounds.

(2) Solvent dewaxing to remove compounds that form crystallike materials at low temperature.

(3) Catalytic hydrogenation to eliminate compounds that would easily oxidize.

(4) Clay percolation to remove polar substances.

d. The various fractions are blended to obtain a finished product with the specified viscosity. Additives may be introduced to improve desired characteristics.

64. Refined lubricating oils are classified as paraffinic or naphthenic according to which fraction is predominant. This varies with the source of the crude. Because aromatics are generally undesirable and are removed, they are seldom mentioned in the product descriptions.

65. Paraffinic molecules tend to form waxy crystallike particles at low temperatures and elevate the pour point, the temperature at which an oil ceases to flow. However, paraffinics have a better viscosity index. Naphthenics behave in an opposite manner; they do not form waxy particles as easily and have a lower pour point, but their viscosity index is poor. Naphthenics are generally reserved for uses where the temperature range is small and a low pour point is required.

Additives

66. Even though oil quality is established by the refining processes, oil can be improved by introducing additives. However, additives alone do not establish quality with respect to oxidation resistance, emulsification, pour point, and viscosity index. The additives are most effective if the oil is well refined. Lubricant producers do not usually state which compound is used in the product; only the generic function is given (e.g., antiwear or EP agents, or oxidation inhibitor). Producers do not always use the same additive to accomplish the same goal. This means that although two brands do essentially the same job, they may not be chemically identical.

67. An additive may function in any of the following three ways:

a. It protects the lubricated surface. Extreme pressure additives and rust inhibitors are in this category. They coat the lubricated surfaces and prevent wear or rust.

b. It improves performance. Viscosity index improvers and antifoaming agents are examples. The oil is made to perform in a desired manner.

c. It protects the lubricant itself. Antioxidants reduce the tendency of oil to oxidize and form sludges and acids. The most common additives are listed in Table 1 and will be discussed individually in the following paragraphs.

Rust inhibitors

68. Rust inhibitors are found in most industrial lubricating oils. Although oil and water do not mix very well, water will become distributed in oil as molecules, an emulsion (especially if the oil contains polar compounds that may develop as the oil ages), or as free water (either suspended by agitation or resting beneath the oil on machine surfaces when agitation is absent). Rust inhibitors prevent water from making contact with machine parts by making the oil adhere better or by emulsifying the water if it is in a low concentration. Some typical rust inhibitors include alkinylsuccinic acids and their derivatives, alkylthioacetic acid derivatives, amine phosphates, and amine sulfonates. However, the producer does not ordinarily report which compound is used.

Oxidation inhibitors

69. Over time, hydrocarbon molecules will react to incorporate oxygen atoms into their structure. The resulting oxides may in turn react among

themselves to form long chain molecules (called polymers) which agglomerate into sludges and varnishlike substances that coat the machine parts. This causes overheating and damages the moving parts. At low temperatures and under minimal exposure to oxygen, this process is very slow. At elevated temperatures and increased exposure to oxygen, the process takes place in a shorter period. Oxidation of hydrocarbons is chemically very complex and depends on the nature of the oil. Additives that reduce oxidation are available; however, a discussion of how they retard oxidation is beyond the scope of this report.

Antifoamants

70. In many applications, air or other gases may become entrained in oil. Unless these gases can be released, a foam is generated. Foam may displace some of the oil and damage the machinery or cause it to operate improperly. Silicone polymers or polyacrylates are added to reduce foaming.

Demulsifiers

71. In most industrial applications, it is undesirable to have emulsified water in the oil. Heavy metal soaps or alkaline earth sulfonates are often used to prevent emulsification. Some oils contain detergents that hold contaminants in suspension to prevent them from collecting on working surfaces. Unfortunately, this also promotes emulsification. If a detergent oil is mixed with an industrial oil containing a demulsifier, the effect of the demulsifier will be reduced or neutralized.

Compounded oil

72. If a small amount of animal fat or vegetable oil is added to a mineral oil, its coefficient of friction will be reduced even though the viscosity is unchanged. The ability of an oil to provide a lower coefficient of friction at a given viscosity is often called its oiliness or lubricity. When fatty oil is added to obtain this quality of oiliness, the lubricant is called a compounded oil. Fatty oil adheres to metal more strongly than mineral oil and provides a protective film. Compounded oils are generally used in worm gears.

Antiwear agents

73. Fatty acids that cause an oil to resist wear by coating the metal surfaces with a layer of the added compound are called antiwear agents. Molecules of the compound are polar and attach (adsorb) themselves to metal

surfaces or react mildly with the metal. When boundary wear (direct contact between metal asperities) occurs, these molecules resist removal more than ordinary oil molecules. This reduces friction and wear. However, they are effective only up to about 480° F (250° C).

Extreme pressure agents

74. Extreme pressure agents react with the metal surfaces to form compounds that have a lower shear modulus than the metal. This reduces friction, wear, and possible galling. The reaction is initiated by increased temperature caused by pressure between asperities on wearing surfaces. Consequently, the reaction creates a protective coating at precisely the points where protection is required. Extreme pressure additives are used in cases of heavy loading or shock loading.

Pour point depressants

75. An oil's pour point is the temperature at which an oil ceases to flow under the influence of gravity. In cold weather, oil with a high pour point makes machinery startup difficult, if not impossible. The stiffness of cold oil is due to paraffin waxes that tend to form crystallike structures. Added polymethacrylates will modify the crystallike structure and reduce the pour point.

Viscosity index (VI) improvers

76. The viscosity index is an indicator of the increase or decrease in viscosity as the temperature is changed by a given amount. The higher the VI, the less the viscosity of an oil changes for a given temperature change. Thus, viscosity index improvers raise the index. These improvers have long chain molecules that coil up when cold and have little effect on the viscosity of thin oil. When heated, they uncoil and interact with the oil to increase viscosity. A thin oil required for cold weather operation is too thin for proper lubrication at high temperatures. The improver increases viscosity at higher temperatures. The overall effect is less change in viscosity for a given change in temperature.

Tackiness agents

77. In some cases, an oil must adhere to surfaces extremely well. Adding polymers composed of long chain molecules or aluminum soaps of long chain fatty acids increases the tackiness or adhesiveness of an oil.

Synthetic Oils

78. Only a few synthetic oils were listed in the lubricant survey conducted during this research. Although there is no widespread preference for these lubricants, they have characteristics that are superior to ordinary mineral oils. Consequently, it would not be surprising if a manufacturer recommended synthetic oil in special cases.

79. Synthetics perform better than mineral oils in the following respects:

a. Better oxidation stability or resistance.

b. Better viscosity index.

c. Much lower pour point, as low as -50° F (-9° C).

d. Lower coefficient of friction.

80. These features are most valuable at either very low or very high temperatures. Good oxidation stability and a lower coefficient of friction permits operation at higher temperatures. The better viscosity index and lower pour points permit operation at lower temperatures.

81. The greatest drawback to using synthetics is their higher cost. Some people in the oil industry believe there is no cost justification for using synthetics between 32° F (0° C) and 350° F (175° C).

Greases

Description of grease and grease lubrication

82. Grease is not just a very thick oil, it is a mixture of a fluid lubricant, a thickener, and other additives. The fluid in 99 percent of grease products is a mineral oil. Thickeners are usually soaps. Although these are the most common ingredients, other ingredients used are listed in Table 2.

83. Grease and oil cannot be substituted. Machinery designed for use with oil requires a costly system to keep the oil distributed on lubricated surfaces. Grease, by virtue of its rigidity, tends to stay in place with less costly retention devices. However, grease does not dissipate heat as well as oil, nor does it carry away contaminants by circulation like oil. The choice

of an appropriate lubricant depends on the operating temperature and the machinery design.

84. The thickeners in grease do not provide lubrication but they help the lubricant stay in place. Grease functions in the following three ways:

a. Serves as a reservoir that releases a lubricating film to the wearing surfaces.

b. Acts as a seal to prevent the lubricant from running off the wearing surfaces.

c. Serves as a temperature-regulated feeding device. If the film between wearing surfaces thins, the resulting heat will soften the adjacent grease which will expand to restore the film.

85. Grease performs somewhat like a liquid and somewhat like a soft solid. Grease offers a resistance to flow, but once moving and being sheared between wearing surfaces, this resistance to flow is reduced. The amount of reduction depends mostly on the viscosity of the oil in the grease.

86. The use of grease as a lubricant has limitations. For example, in hydrodynamic lubrication, the wearing surfaces do not meet except at startup; wear is minimal. Because this method of lubrication requires a fluid lubricant, grease cannot be used. Another limitation is that because grease is not fluid, it cannot dissipate heat through convection. Thus, it invites heating especially at high speeds where its use is limited.

Penetration and NLGI (National Lubricating Grease Institute) numbers

87. Because the most important feature of a grease is its rigidity (or consistency), a method to measure this quality is needed. The measure of consistency is called penetration. To measure penetration, a cone of given weight is allowed to sink into a grease for 5 seconds at a standard temperature of 77° F (25° C). The depth in millimeters to which the cone sinks is the penetration of the grease. A low penetration means the grease is hard. A penetration of 100 millimeters would represent a very hard grease while one of 450 millimeters would be very soft. Table 3 lists the NLGI grease classifications.

Bleeding

88. Bleeding is a condition when the oil in a grease separates from the soap thickener. It is induced by higher temperatures but it also occurs during long storage periods.

Temperature effects

89. High temperatures are more harmful to grease than to oil. Grease lubrication depends on the grease's consistency to hold it in place. High temperatures induce softening and bleeding (separation of the oil). Also, the oil in grease may flash, burn, or evaporate at temperatures above 350° F (175° C). Some grease, calcium soap grease for example, contains a small amount of water that provides a thickener structure. Temperatures above 165 to 175° F (73 to 79° C) will result in dehydration and loss of structure.

90. A second harmful factor related to high temperature is excessive oxidation. Since grease is a soft solid it cannot dissipate heat by convection like a circulating oil. Consequently, if a small hot point exists, the heat is not carried away and the excessive temperature can cause oxidation or even carbonization. The grease can harden or form a crust.

91. If the temperature of a grease is lowered enough, it will become so viscous that it can be classified as a hard grease. Machinery operation may become impossible. The temperature at which this occurs depends on the shape of the lubricated part and the power being supplied to it. Producers' specifications seldom indicate the lowest operating temperature, but the maximum operating temperature is either given on the container or can be obtained upon request.

Dropping point

92. As the temperature of a grease increases, the penetration increases only modestly until a point is reached where the grease quickly liquifies and the desired consistency is lost. The temperature at which this occurs is called the dropping point. It is possible that the grease will not regain its original structure after cooling. The dropping point is not the maximum temperature at which a grease may be used. The maximum operating temperature is below the dropping point. Appendix B lists the dropping points, maximum usable temperatures, and other information on greases.

Effects of water

93. Grease is affected by water to the extent that a soap/water lather may suspend the oil in the grease. Sodium greases change the most; calcium and lithium greases change the least. Calcium, lithium, and aluminum soaps are water insoluble, but as a grease is worked during lubrication, some of the oil and soap may become emulsified and wash away.

Shear stability

94. As a grease is mechanically worked or sheared between wearing surfaces, the consistency may change. The ability of a grease to maintain its consistency when worked is called its shear stability or its work stability.

Pumpability and slumpability

95. Pumpability refers to the ability of a grease to be pumped or pushed through a system while slumpability or feedability refers to its ability to be drawn into (sucked into) a pump. Fibrous greases tend to have good feedability but poor pumpability. Buttery-type greases tend to behave conversely; good pumpability but poor feedability.

Migration

96. The oil in a grease can migrate through the thickener network under certain circumstances. If grease is pumped though a pipe, as in a centralized lubrication system, and encounters a resistance to the flow, the grease may form a plug. In this case, the oil may continue to flow and migrate through the thickener network. This separation of the oil from the thickeners results in increased plugging.

97. If two different greases are in contact, the oils may migrate from one grease to the other and change the structure of the grease. Therefore, it is unwise to mix two greases. Although greases are compatible in many cases, this is not always true. If a grease must be replaced, the old grease should be removed as much as possible.

Contaminants

98. Greases tend to hold solid contaminants on their outer surfaces and protect lubricated surfaces from wear. If the contamination becomes excessive or eventually works its way down to the lubricated surfaces, the reverse occurs; the grease retains abrasive materials at the lubricated surface and invites wear.

Complexes

99. A "complex" grease is made from a salt of the named metal instead of the hydroxide of the metal. This method provides added wear resistance. Generally grease prepared by this method is referred to as multipurpose grease.

Calcium grease

100. Calcium grease, or lime grease, is one of the oldest grease preparations. It is prepared from inedible tallow or animal fat and a small amount of water (about 3 percent). The water is required to modify the soap structure so it can absorb mineral oil. Thus calcium grease is sensitive to elevated temperature. At temperatures above 160 to 175° F (70 to 79° C), dehydration occurs and the structure is lost. In spite of the temperature limitations, lime grease has good water-resistance qualities and is still used today. If a calcium grease is prepared from 12-hydroxystearic acid, the upper temperature limit is raised into the 230° F (109° C) range.

101. Calcium complex greases, prepared by adding the salt calcium acetate, provide extreme pressure characteristics without the use of an additive; however, EP additives may be included anyway. Dropping points as high as 500° F (257° C) can be obtained and the maximum usable temperature can be increased to approximately 350° F (175° C).

102. Due to the good water-resistance qualities and relatively low cost, normal (not complex) lime grease is used where water is present and operating temperatures are low. Of course, a calcium complex grease would perform at higher temperatures but the water resistance is less than that of lime preparations and the cost is higher. Rust and oxidation resistance in calcium complex grease is poor, but it can be improved with inhibitors.

103. Calcium greases are not widely used at Corps hydraulic installations; only three instances were reported.

Sodium grease

104. Sodium grease was developed to overcome the disadvantage of a low required operating temperature for calcium grease. Essentially, it is the opposite of calcium grease; it can be used at temperatures up to 250° F (120° C) but is very susceptible to the effects of water. Sodium is sometimes mixed with other metals, especially calcium, to improve water resistance. In spite of the declining use of sodium grease, it is still recommended for use in certain heavy-duty applications and in some well-sealed electric motors.

105. Although none of the surveyed Corps hydraulic installations reported using sodium grease, two installations reported using sodium-calcium grease.

Soap Thickeners

106. The characteristics of grease (excluding the additive effects) depend to a large extent on the included soap (Table 4). Soap thickeners do more than provide consistency to grease. They may affect the amount of an additive required to obtain a desired quality or they may impart a desired quality due to their presence alone. Therefore, it is important when selecting a grease to be aware of the influences of soaps.

Description of soap

107. Soap is created when a long-chain fatty acid reacts with a metal hydroxide. The metal is incorporated into the long carbon chain and the resultant compound develops a polarity. The polar molecules tend to form a fibrous network that holds the oil. Thus, a somewhat rigid material, or gel, is developed. Of course, when soap and oil are combined to form grease, concentration of the soap can be varied to obtain different grease thicknesses. Furthermore, the viscosity of the oil will also affect the thickness of the grease.

Conventions in naming soaps

108. The most common method of designating a soap thickener is to use the metal from which the soap is prepared (calcium, lithium, etc.). Because soap qualities are also determined by the fatty acid from which the soap is prepared, not all greases made from soaps containing the same metals are identical.

Aluminum soaps

109. Normal aluminum grease is clear and somewhat stringy. When heated, this stringiness increases, producing a rubberlike substance that pulls away from metal surfaces and reduces lubrication. Because of this quality, operating temperatures are limited to less than 175° F (79° C). Aluminum grease has good water resistance and inhibits rust without additives, but it tends to be short lived and has relatively poor shear stability.

110. Aluminum complex grease is comparable to other complex greases but is not widely used. However, several Corps hydraulic installations reported using aluminum complex grease.

Lithium soaps

111. Compared to other soaps, lithium is by far the most popular. The normal grease contains lithium 12-hydroxystearate. This grease has a dropping point around 400° F (202° C) and can be used at temperatures up to about 275° F (134° C). It can also be used at temperatures well below zero. It has good shear stability and a relatively low coefficient of friction, which permits higher speeds. It has good water resistance, although not as good as calcium or aluminum. Its greatest disadvantage is that it does not naturally inhibit rust, but rust prevention can be obtained through additives.

112. Complexed lithium grease is generally considered to be the nearest thing to a truly multipurpose grease and is used extensively at Corps hydraulic installations.

Other soaps

113. Barium and lead soaps are also used in grease. Although lead provides extreme pressure characteristics without additives, concerns with lead toxicity probably will reduce use.

Other Thickeners

114. As indicated by Table 2, thickeners other than soaps are available. Although most of these are restricted to very special applications, two are worthy of mention. Polyurea grease has outstanding resistance to oxidation because it contains no metal soaps that tend to invite oxidation. The dropping point and maximum operating temperature are close to those of multipurpose greases but the shear stability is poor and rust inhibitors are required. It is generally used with all types of bearings but has been particularly effective in ball bearings.

115. Organo clay grease has outstanding temperature resistance. The maximum operating temperature for this grease is limited by the included oil which can flash, evaporate, or burn at temperatures above 350° F (175° C). However, many of the multipurpose greases may be operated above this temperature for short periods if the grease is changed after an hour or so. The limiting factor then becomes the dropping point. Since clay does not melt at low temperatures, it can be used at temperatures near 500° F (257° C) for short periods. Organo clay grease also has excellent water resistance but in other respects it does not perform better than other greases.

PART IV: SELECTING LUBRICANTS

Classifications and Specifications

116. The fundamental key to selecting a lubricant lies in being able to interpret what the producer says about the product and being aware of conventions in classifying oils. Without such a background, it is virtually impossible to make a reasonable selection or substitution.

117. Professional societies and organizations have established classifications for oil and grease. The most widely encountered systems are those of the following organizations:

- SAE (Society of American Engineers)
- AGMA (American Gear Manufacturers Association)
- ISO (International Standards Organization)
- NLGI (National Lubricating Grease Institute)

Oil classification

118. Oil is normally classified by viscosity grade, additives, use, as nonspecialized, or by the producer's brand name.

a. Classification by viscosity grade. This classification is the most common method of describing an oil. The most common classification systems are those of the SAE, AGMA, and ISO. Each organization uses a different kinematic viscosity range numbering system. Appendix A lists these systems and contains a conversion chart.

b. Oil classification by additives. Oil may be further classified by the additives as follows:

- Inhibited or R&O (rust and oxidation inhibited)
- AW (antiwear)
- EP (extreme pressure)
- Compounded
- Residual

(1) The first three classes require no explanation; they contain the indicated additives. Compounded oil contains from 3 to 10 percent of an acidless animal fat or tallow. It is also called steam cylinder oil. The added fat reduces the coefficient of friction in situations where an extreme amount of sliding friction occurs. A very common use would be in worm gear systems. Compounded oil may be composed of either a normal mineral oil or a residual oil depending on the desired viscosity.

(2) Residual oil is that which remained as residuum after the lighter oil was distilled off during refining. It

contains a relatively high proportion of asphalt which makes it adhesive. It is often used for open gear systems (tackiness agents are added to increase adhesion). Often, open gear compounded oil is so heavy a solvent is required to soften it for application. (The solvent evaporates after application.) This heavy oil should not be confused with grease. Residual oil with lower viscosity is also used in many closed gear systems. Compounded oil may contain residual oil if the desired viscosity is high.

c. Classification by use. Classification according to use arises because refining, additives, and type of petroleum (paraffinic or naphthenic) may be varied to provide desirable qualities for a given application. Some of the more common uses are:

- Engine oils
- Marine engine oils
- Aircraft oils
- Quench oils (used in metal working)
- Cutting oils (coolants for metal cutting)
- Paper machine oils
- No-drip-oils (textile and food handling machinery)
- Insulating oils
- Way oils
- Wire rope or chain lubricants

Some of these are very specialized oils and only two, insulating oils and wire rope or chain lubricants, have been identified at Corps hydraulic installations. Of course, engine oils are used in automotive applications.

d. Nonspecialized industrial oil. It is difficult to find a specific name in petroleum terminology to refer to this category. Consequently, this term has been selected to describe those oils which are not formulated for a special application. (Producer literature often uses the term general purpose oil.) Nonspecialized industrial oil is generally divided into two categories: general purpose and EP gear oils.

(1) General purpose oils contain R&O additives, AW agents, antifoamants, and demulsifiers. They may be used in almost any mechanical application if a specialized oil is not required. Their ISO viscosity ranges from about 32 to around 460. These oils are often referred to as R&O oils or hydraulic oils even though they may contain other additives and are not intended exclusively for hydraulic use. Some of these oils are more highly refined and provide longer life and better performance than others. These are usually referred to as turbine oils or premium grades. Although used in turbines, the name turbine oil does not mean it is restricted to use in turbines; it refers to the quality of the oil.

(2) EP gear oils generally have a higher viscosity range, from about ISO grade 68 to around 1,500. These may be regarded as general purpose oils with EP additives. Although these oils are probably more commonly used in gear systems, they can be used in any application where their viscosity range and additives are required. Gear oils should not be confused with SAE gear oils which are formulated differently and are not discussed in this study.

e. Producer brand names. Oil producers often identify their products by whimsical names which may or may not indicate one of the standard classifications. Tribol 771, a product of Imperial Oil and Grease Company, tells nothing of its class, but Conoco's Dectol R&O Oil 32 indicates it is an R&O oil with an ISO viscosity of 32. Regardless of how much information may be reflected in the brand name, it is never enough to make a selection. A user must refer to information brochures provided by producers to determine the intended use, additives, and specifications.

Producers' oil brochures and specifications

119. Oil producers provide product information in brochures, booklets, or on the oil container. Although the amount of information varies, the format generally includes the intended use, the additives and oil type (i.e., paraffinic, naphthenic, synthetic, compounded, etc.), and the specifications.

120. Some producers may identify the product by its usage classification although they may not use the same names given in this report. Others may simply give the machinery classes where the product can be used. Often, both methods of identification are used. (See the three fact sheets for Conoco's Redind, Dectol, and Turbine oils in Appendix C.) Intended use can be misleading. All three of the Conoco oils can be used for electric motors and general purpose applications, but not all three are to be used throughout the machinery. Redind oil contains no oxidation inhibitors and is intended for use where the oil is frequently replaced. The Dectol line is an R&O oil with the usual antifoaming and demulsifying agents. AW agents are also included. The Turbine oil is similar to Dectol except that the refining method and additive package provide greater protection. One Turbine viscosity grade, ISO 32, is treated to resist the effects of hydrogen used as a coolant in generators.

121. Producers do not usually list additives. Instead, they indicate characteristics such as good antiwear qualities, good water resistance, or

good oxidation resistance. The user can assume that since oil does not naturally have such qualities to a desirable extent, an agent has been added to obtain the given quality. Product literature also gives the oil type (i.e., paraffinic, naphthenic, residual, compounded, or synthetic).

Producer specifications

122. Producer specifications amount to a certification that the product meets or exceeds listed physical characteristics in terms of specific test values. The magnitude of chemical impurities may also be given. Producers vary somewhat in the amount of information in their specifications. However, kinematic viscosity (centistokes) at 104 and 212° F (40 and 100° C), SUS (saybolt viscosity) at 100 and 210° F (37 and 98° C), API gravity, pour point, and flash point are generally listed. Other physical and chemical measurements may also be given if they are considered to influence the intended use. Appendix C contains typical specifications for oils.

Grease classifications

123. Grease is classified by penetration number and by soap or other thickener. Penetration classifications have been established by NLGI and are given in Appendix A. ASTM test D 217 is the standard for performing penetration tests. A penetration number indicates how easily a grease can be fed to lubricated surfaces (pumpability) or how well it remains in place. Although no method exists to classify soap thickener, the producer indicates which soap is in the product. The soap thickener indicates probable water resistance and maximum operating temperature and gives some idea of pumpability. Although these are important factors, they are not the only ones of interest. These simple classifications should be regarded as starting requirements to determine a group of appropriate grease types. The final selection must be made on the basis of other information provided in the producer's specifications. Viscosity of the oil included in a grease must also be considered.

Producer grease brochures

124. Producers also provide information and specifications for grease. Grease specifications normally include soap thickener, penetration, included oil viscosity, and dropping point. The producer may also include water washout or wear test information.

125. Grease additives are not usually given unless solid additives such as molybdenum disulfide or graphite are included. If solid additives are

used, the producer will often state this emphatically and the product name may indicate the additive.

Principles of Selection

Manufacturer recommendations

126. Selecting a lubricant is not a straightforward singular act; it is a combination of approaches that have developed over time. The prime considerations are film thickness and wear. Although film thickness can be calculated, the wear properties associated with different lubricants are more difficult to assess. Lubricants are normally tested by subjecting them to various types of physical stress. However, these tests do not completely indicate how a lubricant will perform in service. Experience has probably played a larger role than any other single criterion. Machine manufacturers have learned which classes of lubricants will perform well in their products.

127. Professional societies have established specifications and classifications for lubricants to be used in a given mechanical application. For example, the AGMA has established specifications 250.04 and 251.02 for enclosed and open gear systems, respectively. Such specifications have been developed from the experience of the society's membership for a wide range of applications. Thus, any manufacturer has access to the collective knowledge of many contributors.

128. The manufacturer's recommendation should not necessarily be considered the best selection. The concept of best selection is unrealistic. In spite of a consensus regarding what lubricant to use in a given application, individual manufacturers may have different opinions based on their experience and equipment design. However, the manufacturer is probably in the best position to recommend a lubricant. This recommendation should be followed unless it fails to perform satisfactorily.

129. A manufacturer generally does not recommend a single specific brand name. Physical qualities (such as viscosity or penetration number), chemical qualities (such as paraffinic or naphthenic oils), or test standards are specified. However, a number of brands that meet the manufacturer's specifications may be cited.

Producer recommendations

130. Since manufacturers specify appropriate lubricants for their products in terms of specifications or required qualities rather than particular brand names, the user is faced with identifying which brands meet the requirements. By following directions given in Part IV, the user should be able to identify appropriate products. However, it is better to consult with the lubricant producer to obtain advice on which products most closely meet the specifications.

131. Many lubricant producers maintain technical staffs (product engineers) to advise users in selecting lubricants and answer technical questions regarding lubricants. Given a manufacturer's description and lubricant specification, product engineers can identify which of their company's lubricants meet the manufacturer's specifications. A producer may carry several products that meet specifications, but one might be of premium quality and carry a higher price or be intended for some special use that would not be of benefit to the user. Furthermore, the user might be operating the equipment under unusual or unique circumstances that could impose additional requirements unforeseen by the manufacturer. In effect, the product engineer converts the manufacturer's specifications into an appropriate brand based on the user's specific circumstances.

132. The producer not only supplies lubricants, but serves as an important link between the equipment manufacturer and user. In effect, the producer interprets the manufacturer's intentions and provides advice when specifications are absent or when a lubricant does not perform satisfactorily.

User selection

133. The user should ensure that certain criteria are met regardless of who makes the selection. The selection should be in the class recommended by the machinery manufacturer (i.e., R&O, EP, etc.) and be in the same base stock category (paraffinic, naphthenic, or special synthetic). Furthermore, physical and chemical properties should be equal to or better than those specified by the manufacturer. Viscosity should be exactly the recommended grade. If a recommendation seems unreasonable, the user should question the suitability of the manufacturer's recommendation or ask a different lubricant producer for a recommendation.

134. Generally, the user should follow the manufacturer's specification. If the manufacturer's specifications are not available, which lubricant was in use? Did it perform satisfactorily? If it performed well, continue to use the same brand. If that is not feasible, select a brand with specifications equal to or better than those of the brand previously used. If a previous lubricant performed poorly, it is probably best to rely on the recommendation of a product engineer or possibly get several recommendations.

135. Generally, the user will make a selection in either of two possible situations:

a. He will substitute a new brand for one previously in use.

b. He will select a brand that meets the manufacturer's specifications. This will be accomplished by comparing producer's specifications with those of the manufacturer.

136. In either case, the selection starts by using a substitution list. Most lubricant producers maintain such a tabluation but use different names. A substitution list usually gives the products of major producers and an equivalent lubricant of the publishing producer which he maintains has comparable specifications.

137. Substitution lists are useful but they have their limitations. They are not subdivided by classes of lubricants. Furthermore, it is difficult to do more than compare a lubricant of one producer with one given by the publishing producer. For example, a Conoco substitution list can be used to compare Quaker State products with Conoco or Shell with Conoco, but comparing Quaker State and Shell cannot be done unless Conoco has a product equivalent to products of both Quaker State and Shell. A user would need substitution lists from many producers to be able to effectively select more than one option. Many producers claim they do not have a list or are reluctant to provide it.

138. The publishers of Plant Engineering have prepared a universal list, the PE list. The PE list correlates products of over 100 producers by class of lubricant (Appendix D).

139. Although substitution lists are helpful, they cannot solve user's problems in making a selection. A substitution list is valuable because it correlates the array of whimsical brand names used by producers. Furthermore, it eliminates producers who do not have the desired product in their line. A

substitution list should be regarded as a starting tool to quickly determine likely products. The lists do not imply that lubricants listed as being equivalent are identical. The lists do indicate that the two lubricants are in the same class, have the same viscosity, and are intended for the same general use. Selection must finally be made from information brochures provided by the producers.

140. The user should use the producer's brochure to determine the following:

- a. The viscosity is the one recommended by the manufacturer or is the same as a previously used lubricant that performed well. When a grease is considered, the viscosity of the included oil should be the same as the previous lubricant.
- b. The intended use given by the producer corresponds to the application in which the lubricant will be used.
- c. The class of lubricant is the same as that recommended by the manufacturer or the same as a previously used lubricant that performed well. If the manufacturer recommended an R&O or EP oil or a lithium No. 2 grease, that is what should be used.
- d. The specifications should be equal to or better than those recommended by the manufacturer or those of a previously used lubricant that performed well.
- e. The additives should perform the required function even though the additive may not be chemically identical in several possible lubricants.

Using the PE substitution list

141. Each class on the PE list is divided by horizontal lines and is further broken into viscosity grades under the column marked ISO viscosity grade. The ISO grading system is most common for industrial oils. Use Appendix A if you wish to convert to SAE or AGMA equivalents. The column marked Viscosity, SUS at 100° F (37° C) indicates the viscosity range in SUS for a given ISO grade. For example, the viscosity of an ISO grade 150 can be anywhere between 135 and 165 SUS at 100° F (37° C). The viscosity is usually near the midpoint (in this case 150 SUS). The numbers in the PE designation refer to the midpoint SUS. Products are available in viscosities not given on the PE list. For example, Exxon's Spartan EP line has viscosities ranging from ISO 68 to 2200, not just the ISO 68 and 320 given in the PE list. The same is true for other classes in the PE list.

142. The classes of oil are indicated under the column marked Lubricant Type. Three of the classes, fire resistant hydraulic oil, spindel oil, and way oil were not indicated in the Corps survey as being used. One of the last three classes on the list is a special preparation for open gears and the other two are classes of grease.

143. The remaining four classes (hydraulic and general purpose oils, AW hydraulic oils, gear oils, and EP gear oils), are best described by comparison with the nonspecialized industrial oils discussed earlier. Nonspecialized oils contain a category called general purpose oils. This term is also used in the PE list. To prevent confusion, the PE general purpose category will be referred to as the first PE group (which denotes its position in the list). Both the first PE group and the PE gear oils correspond to general purpose oils. Gear oils, as used in the PE list, refer to oils with a higher viscosity that would most likely be used in gear systems. Note that the same brand names appear in both categories and that they differ only in viscosity. However, both of these categories differ from the previously described general purpose oil in that the additives may not be the same. In most cases, the first PE group and PE gear oils are exactly the same as general purpose oils. However, in some cases, brand names indicate EP additives have been included. In other cases, AW is given instead of R&O. This raises the possibility that R&O additives are not present. AW hydraulic oil is a general purpose oil but its antiwear properties are sufficient to pass the Vickers vane test for hydraulic applications when this is required.

144. The EP gear oils should correspond to those described under nonspecialized industrial oils except that EP additives are included and viscosities may be as high as ISO 2200. The PE classification of gear oil should not be confused with the SAE gear oil classification which is for use in automotive gear systems. SAE gear oils are formulated differently and are not discussed in this study.

145. Since grease preparation varies greatly among producers, only two types are given in the PE list: No. 2 Lithium EP and molybdenum disulfide EP No. 2. These are the two most widely used industrial greases. The name molybdenum disulfide to designate lubricant type does not reflect the type of soap, but it will usually be lithium. While both types are intended to

provide extra protection against wear, one contains EP additives and the other contains molybdenum disulfide.

146. Although the Corps generally uses lithium greases (60 to 70 percent of the time), calcium, aluminum, polyurea, and sodium calcium are also used. Furthermore, the survey indicated that greases ranging from NLGI 00 to No. 3 are being used; about 65 percent of No. 2 and 20 percent of No. 1. Consequently, in many cases, the PE tables will not be useful for selecting greases.

147. The cling-type gear shield lubricants are residual oils to which a tackiness agent has been added. They are extremely adhesive and so viscous that solvents are added to permit application. After application, the solvent evaporates leaving the adhesive viscous material. Some products contain no solvent and must be heated to reduce viscosity for application.

148. Compounded oils are not included in the list as a separate class. When these oils are required, producers must be contacted directly.

149. In cases where the PE list cannot be used, the most simple process is to contact product engineers and ask for product brochures. By obtaining the recommendations of several preferably large and reputable producers, a user can critically evaluate the recommendations.

Lubrication of Machinery Components

150. Instead of considering lubrication for an entire complex mechanical system such as those found at Corps hydraulic installations, it is more feasible to address lubrication for the individual mechanical components. To begin with, R&O additives are so common today and specified by so many manufacturers, using lubricants without them would be unjustified. Introducing an oil without R&O additives into a stocking system would probably do no more than increase the possibility of accidentally adding the wrong lubricant.

Journal bearings

151. A journal bearing is the sleeve fitted around a rotating shaft (the journal) to provide a wearing surface. The terms sleeve bearing and plain bearing are also used. Journal bearings may be lubricated with either oil or grease. If oil is required, a wear resistant general purpose R&O oil of recommended viscosity, with antifoaming and demulsifying agents, is often

sufficient. If severe or shock loading is involved, an EP oil may be recommended.

152. Generally, oil is better than grease as a lubricant for journal bearings. Where clearance between a journal and its bearing is relatively large, speed is low, and shock loading is involved, grease is used. NLGI No. 2 or No. 1 are most commonly used. Since there is a relatively large contact area in journal bearings, from which heat is not easily transferred, NLGI grease numbers greater than No. 2 are not commonly used.

153. Flexible plate thrust bearings are closely related to journal bearings in that they, like some journal bearings, are hydrodynamically lubricated. A well-refined general purpose R&O oil of recommended viscosity, with antifoaming and demulsifying agents, is the universal lubricant, but in some cases premium or turbine quality oil may be recommended. The use of EP agents is not required for hydrodynamic operation since wearing surfaces are completely separated by the oil film.

Antifriction bearings

154. Antifriction (ball or roller) bearings are lubricated with either oil or grease as designated by the manufacturer. These bearings function on the elastohydrodynamic principle and depend more critically on viscosity to maintain film thickness. Because viscosity varies with temperature, it is the viscosity at operating temperature that is important, not the published viscosity based on standard temperatures. Most manufacturers follow the guidelines listed in Table 5.

155. The question that remains, however, is: "Which standard viscosity will have the required viscosity at the temperature of operation?" The manufacturer ordinarily provides this information, but producers can also provide the information.

156. Rust is particularly damaging to antifriction bearings which depend on extremely smooth surfaces to provide prolonged life. Even very small rust pits reduce smoothness and the life of a bearing. Consequently, it is important that an antirust additive be included in the selected oil. A well-refined general purpose R&O oil with antifoaming and demulsifying agents will ordinarily be recommended. EP additives are used when the machine is frequently stopped and started, when heavy or shock loading is present, or when sliding motion is excessive. Otherwise, they are not usually required.

157. Because of the variety of greases found in the market today, grease selection is more difficult than oil selection. As always, the manufacturer's recommendation should be followed. When the recommended grease is not available, a substitute is required. NLGI No. 2 is the most commonly used grease. If low ambient temperatures are involved, No. 1 may be recommended, and if the grease is dispensed from a central system, No. 0 may be recommended. For higher speeds, No. 3 or even No. 4 may be required. Grease containing a lithium complex thickener is most frequently used, and if there is no other recommendation, Lithium No. 2 is the best to start with. Calcium complexed greases may be recommended, especially where water is a likely contaminant. Sodium greases are seldom recommended, and they resist water very poorly. Because of the critical role viscosity plays in EHD lubrication, particular attention should be given to the viscosity of the oil in the grease.

158. Rust and oxidation inhibitors should be included in a grease for the same reasons they are included in oil used in antiwear bearings. Solid EP additives, such as molybdenum disulfide or graphite, are often included in grease intended for heavy duty use. These substances are of no substantial benefit in antifriction bearings but they are not detrimental either.

Gears

159. Oil is ordinarily preferred for both open and closed gears, but the oil for open gears is a heavy residual oil that often contains tackiness agents and is extremely adhesive. Gear oil should not be confused with grease. Grease is also used for gear systems but most designers avoid grease unless there is some special reason. Table 6 lists appropriate lubricants for various gear types and loads.

160. Because of the wide differences in configuration and application, it is difficult to make broad generalizations regarding lubrication for enclosed gears. Viscosity recommendations cover a broad range and the use of EP additives depends entirely on the gear's design. The AGMA prepared specification 250.04, Lubrication of Industrial Enclosed Gear Drives. Although selection cannot be made entirely on this publication, it should provide a reasonable guide when no better recommendation is available. A portion of this publication is given in Appendix E.

161. Open gears are usually lubricated with heavy residual oil containing tackiness agents. These lubricants are extremely adhesive and tend to collect

dust and sand particles that can build into an abrasive cake. In extremely dusty environments, this problem can become severe. A common remedy is to clean the gears using an agent such as Stoddard solvent. However, some producers feel there is an alternative. They suggest that, in some cases, an NLGI No. 2 grease with a tackiness agent and an EP additive can be used. The theory is that the lighter consistency of No. 2 grease allows particles to be flushed from between the gear teeth instead of forming a cake. AGMA Specification 251.02, Lubrication of Industrial Open Gearing, provides information to help select an appropriate product. A portion of this publication is given in Appendix E.

162. Worm gears involve a much greater degree of sliding motion than other types of gears. Bronze is most commonly used for the worm because it has a naturally low coefficient of friction. To further reduce friction, compounded oils are used. EP additives may also be recommended. The contact area in worm gears is greater than in other types of gears. Although this reduces the load per unit area, worm gears tend to operate at higher temperatures than other gear types. Consequently, oil for worm gears is heavy bodied. Oil suitable for worm gears is commonly classed as a heavy bodied steam cylinder oil.

Electric motors

163. Either plain bearings (sleeve) or antifriction bearings may be found in electric motors. Previous discussion about selecting lubricants for these bearing types also applies to electric motors. However, manufacturers and producers strongly emphasize that the level of lubricant in electric motors is very critical. In many cases, motors that are equipped with plain bearings and use oil are ring lubricated. If the oil level in the reservoir is so low that the ring does not dip into the oil, the bearings will be starved and damaged. If the reservoir is too full, the oil might get into the windings and cause damage. If grease is used for antifriction bearings, excessive grease may cause churning and undesirable heating.

Hydraulic systems

164. Although viscosity is always the most important consideration in selecting an oil, it is particularly true in hydraulic systems. Selection depends largely on the type of pump that is used in the system. Gear pumps use relatively heavy oils while vane pumps use lighter oils. If the viscosity

is too low in either case, "chattering" may occur. No generalization can be made regarding viscosity for piston pumps; it varies over a wide range.

165. Oil for a hydraulic system should be heavy enough to seal spaces between the pump components and to minimize wear. On the other hand, if it is too thick, excessive drag and power loss will develop. Hydraulic pump manufacturers always specify viscosity limits for operation and, in many cases, they will give maximum startup and minimum operating limits. Recommended viscosities usually fall between 70 and 250 SUS at operating temperature.

166. Because the oil viscosity should remain within certain limits during operation, the VI should be considered when selecting an oil. It need not be any higher than demanded by local temperature ranges, but since there is no simple way for a user to make a reasonable estimate, it is probably best to use an oil with VI in the range of 95 to 100. Since paraffinic oils have better VI, oils formulated specifically for hydraulic use are of that class.

167. Foaming can be a problem in hydraulic systems. Although manufacturers can, and do, control foaming in the design of their hydraulic systems, hydraulic oils should contain antifoaming agents.

168. Condensation can develop in a hydraulic system and cause corrosion. To reduce the level of water in the oil, a demulsifying agent should be included.

169. Finally, since there is a large amount of sliding motion involved in hydraulic systems, antiwear agents are usually specified and, in some cases, the oil may be required to pass the Vickers vane test.

Compressors

170. Compressors are essentially pumps. There is virtually no difference in the fundamental functioning of a compressor and a pump. What is different is that a compressor pumps air while a pump pumps a liquid such as water or oil.

171. Condensation and the presence of oxygen cause problems for lubrication in air compressors. In some cases, heavy-duty use and high temperatures are also involved. Compressed air exposes the oil to much more oxygen than in other systems of lubrication and, where temperatures are high, oxidation is accelerated. Consequently, the ability of a lubricant to resist oxidation and

rust is of much greater concern in a compressor than in most other applications.

172. The expected severity of oxidation and condensation establishes the type of oil that a manufacturer will recommend. When temperatures are high and the operation is heavy duty, conditions are similar to those within cylinders of an internal combustion engine. In such a case, automotive oils or automatic transmission oils may be recommended. If neither excessive temperature nor excessive condensation is anticipated, an R&O oil from naphthenic base stocks is normally preferred. In cases where the VI is a matter of concern, a paraffinic oil may be recommended. Turbine oils may also be specified. Normally, naphthenics are recommended unless the VI is a major concern. When condensation cannot be sufficiently controlled, compounded naphthenic oils may be recommended. These oils contain fatty acids and other compounds that strongly adhere to metal surfaces and reduce contact with water that might be present. These oils also provide emulsifying qualities. They are more prone to oxidation than uncompounded oils and are restricted to special applications. They should not be used unless specified by the manufacturers. In special cases, synthetics are recommended to obtain improved rust and oxidation inhibition, a better VI, and a lower pour point.

173. When gases other than air are used in a compressor, harmful chemical reactions, other than oxidation of the oil, may occur. Refrigeration systems, for example, usually require either special preparations of oil or nonpetroleum lubricants to retard the unwanted reaction. A discussion of those lubricants is beyond the scope of this report.

Wire rope and chains

174. Wire rope and chains are not manufactured to hold lubricants in place. The strands of wire rope and the sleeves of chains will hold a lubricant to some extent, but eventually the lubricant will be worked out from between the wearing surfaces. Furthermore, there is no system to continuously resupply the lubricant as it is lost. Although chains are sometimes passed through baths or under jets, the supply is not strictly continuous. In addition, wire rope and chain systems are often exposed directly to the atmosphere and elements of weathering and abrasive contaminants. These factors impose a requirement for above ordinary adherence.

175. Heavy oil with a high asphaltic content provides the best adherence. Heating, or the use of solvents, may be required for application. If a dip system is present, thinner oils of appropriate viscosity are recommended.

Insulating oil

176. Although insulating oil is not intended for lubrication, it is used at Corps hydraulic installations. Selecting insulating oil is simple compared to selecting lubricating oil. ASTM specification D 3487 is the standard which governs the quality of insulating oil. All producers meet these specifications with the exception of impulse strength, which varies among producers. However, the producers publish test data and a user can easily determine if the product meets requirements. It is also possible that water content is above the limits set in ASTM D 3487 because of condensation in shipping containers or transport tankers. Users should sample and test insulating oil for its water content upon delivery and before introduction into electrical equipment. The contractor delivering the oil is ordinarily held responsible for meeting specifications, not the producers.

PART V: PROBLEMS FOUND IN THE SURVEY

177. It was initially assumed that problems voiced by several field installations reflected widespread lubricant problems, although the survey conducted during this research did not indicate that problems were widespread. To determine the extent of lubrication problems, 15 points of contact designated by district offices during the Phase I survey were asked to determine if any of the problems mentioned in the survey were being experienced in their districts. Also, staff members of operations or design sections were asked to determine if such problems had been reported. Although no significant complaints were uncovered, it was concluded that the absence of problems given in the survey truly reflected field circumstances.

Lubricant Breakdown

178. In the broadest sense, breakdown or decomposition of lubricants refers to chemical alteration resulting in loss of desired properties. When oil and grease are oxidized, they produce sludge or varnish that causes heating and contributes to corrosion. In some cases of breakdown, additives are depleted. Dust particles, solvents, or corrosive agents might contaminate a lubricant. All of these possibilities might be referred to as breakdown or decomposition.

179. Breakdown does not imply that oil molecules are broken into smaller molecular weight components, resulting in lower viscosity. However, contamination with a solvent or oil of lesser viscosity can result in reduced viscosity. Discoloration due to aging does not necessarily indicate breakdown.

180. Field personnel often refer to the separation of the oil in a grease from the thickener as breakdown. Although separation does indeed thin the grease or increase its penetration, it does not necessarily indicate any chemical alteration. Long-term storage or excessive heat can also induce separation.

181. The Corps survey did not identify any cases where an oil failed or broke down. This is not surprising. Oils used at Corps hydraulic installations have been studied by producers for years and have been improved to very high levels of performance. Manufacturers have also learned the

appropriate oils to use for a given application and the oil producers have developed such a wide variety of products that almost any demand can be met. If the recommended lubricant is properly applied, the probability of failure due to the oil itself is minimal.

182. In one case, the oil was reported to be breaking down in a speed reducer, but it was suspected the oil had been in place for 34 years (since 1951). After such long service, any oil can be expected to oxidize, darken, and become sludged. This case was not regarded as a problem with the oil.

183. A few complaints about the grease or gear dressing for open gears were documented. No trend in either the product or the function could be identified and maintenance personnel have made changes to obtain satisfactory performance.

Compatibility

184. Many individuals believe that catastrophic failure follows if two incompatible lubricants are mixed. That is seldom, if ever, the case and the misunderstanding arises due to what is meant by incompatibility. Incompatibility ordinarily refers to the failure of one lubricant to match the qualities of another with which it will be mixed. This might occur when makeup is added or a new product is introduced. For example, if an oil with no oxidation inhibitor were added to one containing an inhibitor, the effect would be to dilute the inhibitor concentration in the mixture. The extent of dilution would depend on the amount of uninhibited oil added. A similar example would be if a general purpose oil is added to a compounded oil of the same viscosity. Fats used in the compounded oil to provide greater lubricity would be diluted proportionate to the amount added. Using the wrong lubricant could result in damage to machinery in a very short time, but this is not usually a matter of compatibility.

185. In any of these cases, catastrophic failure would not be an immediate consequence. If the dilution were very small, there would be essentially no difference in performance. Even if the dilution were quite large, catastrophic failure would not follow immediately but the life of either the oil or the machinery would be reduced. In this sense, compatibility refers to dilution of a desired additive or quality.

186. There are cases where this definition (i.e., unmatched qualities) would not be appropriate. One oil might contain an additive that would neutralize an additive in the other oil. Motor oils, for example, contain detergents that keep contaminants and water suspended in the oil. General purpose industrial oils contain demulsifiers to retard the suspension of water. Mixing one with the other would counteract the desired effects of either one. Again, the degree of mixing would influence the extent of quality reduction. The viscosity would remain unchanged and lubrication would continue with no catastrophic failure. However, the life of the machinery would probably be reduced if the condition continued for an extended period of time.

187. Incompatibility can also occur if the oil contains a corrosive additive. EP additives can sometimes be corrosive to bearings made of alloys. Zinc dialkyl dithiophosphate is a widely used additive that provides wear reduction but has a corrosive effect on lead-bronze bearings. Copper alloys react with acid succinates to yield a soluble copper complex that promotes oxidation of the oil.

188. These cases would seem to imply that compatibility is always a problem, but in practice, a few simple rules will virtually eliminate incompatibility problems:

a. Select an oil from the same class as the one being used. Brand names do not make a great deal of difference; oils within a given class are all quite similar. The various classes that might be encountered were discussed in Part IV.

b. The selected oil should have equal or better specifications than the one with which it will be mixed.

c. The lubricant should meet or exceed the manufacturer's specifications.

d. If machinery is known to contain bearings made of an alloy affected by certain additives, the manufacturer will normally notify the user. Orders for oil should prohibit inclusion of such additives.

189. The compatibility between acid-refined and hydrogen-refined oils has been questioned. The purpose of any refining process is to remove undesirable constituents within the oil. In either acid or hydrogen refining, the primary objective is to remove unsaturated hydrocarbons (the full complement of hydrogen is not present). Unsaturated hydrocarbons are chemically more reactive than saturated hydrocarbons and are more susceptible to oxidation.

They may be eliminated in either of two ways. In hydrogen refining, hydrogen is added to provide saturation. In other words, unsaturates are converted to saturates which are less susceptible to oxidation. Nothing is removed from the oil; it is simply converted.

190. In acid refining, sulfuric acid is added and reacts with unsaturates to form sulfur compounds that can be selectively removed from the oil. The reacted sulfur compounds form a sludge and its disposal has become an environmental problem. This has caused a shift to hydrogen refining.

191. In either case, the product is essentially the same. In hydrogen refining, unsaturates are converted to saturated hydrocarbons and in acid refining, the unsaturates are removed, leaving saturated hydrocarbons. However, there are slight differences. No two oils are exactly the same unless taken from the same refined batch. Furthermore, hydrogen refining does remove certain aromatics somewhat more effectively than acid refining. Such differences are so minor that these oils can be mixed with no problems.

192. Compatibility between these two refined types comes into question in insulating oils. In earlier years, acid-refined naphthenic base stocks were used for insulating oils. (As discussed in Part III, these oils have a lower pour point than paraffinics.) In more recent times, oil producers faced with dwindling sources of naphthenic crudes began producing paraffinic insulating oils. This occurred at about the same time that hydrogen refining replaced acid refining. Consequently, older transformers are very likely to contain acid-refined naphthenic oil. However, when new makeup oil is purchased, it may be a paraffinic hydrogen-refined oil.

193. The refining process differences lead to suspicions of compatibility problems. However, the only significant difference is the fact that paraffinics provide a higher pour point. Although this is of little concern in warm climates, it could be significant in very cold climates.

194. Lubricating oils may be either paraffinic or naphthenic depending on intended use, but there are no restrictions on availability. If one type is being used, there is no problem in acquiring more of the same. Differences in the refining processes are of no consequence.

195. Greases may be incompatible in a different manner than oils. In a few cases, greases may lose their structure when mixed. Although this is

not common, it is most likely to occur when greases with two different soap thickeners are mixed. The result is unpredictable. The best policy is to not mix different brands of greases. If a new brand of grease must be introduced, it should be injected in such a manner that the old is forced out as much as possible. Greases may also be incompatible in the same sense as oil. That is, if the addition of new grease in any way reduces characteristics below specifications for the original grease it may be considered incompatible. The only reliable way to determine compatibility between two greases is to test them. A more simple solution is to avoid mixing them.

Cold Weather Effects

196. The viscosity of any oil increases as the temperature decreases. Often this increase is sufficient to cause a considerable increase in power requirements for machinery operation. When the condition is extreme, machinery may become inoperable. The traditional methods of remedy have been to either provide a heating device to warm the oil to an acceptable viscosity or to simply change the oil to one with a lower viscosity. Oil producers and machine manufacturers indicate that the only other alternative is to use a synthetic oil. Synthetics have much lower pour points and better viscosity indexes. Although heaters are frequently used in northern districts, synthetics are used in at least one case to reduce cold weather effects.

High Priced Proprietary Lubricants

197. The survey also attempted to identify any high-priced proprietary lubricants recommended by equipment manufacturers with the threat that warranties are not honored unless the recommended lubricant is used. The lubricants used at Corps installations are all competitively priced products and, while there are undoubtedly differences in prices, there is nothing to suggest they could be considered high priced. Furthermore, the survey did not indicate that use of a given brand had been specified by the manufacturer. Since most of the lubricants used are very common preparations, there should be no reason to pick a particular brand.

Machinery Failures

198. Only two cases of machinery failure were mentioned in the survey. The first case involved failure of the gear reducer on a fish pump. The second case involved two overheated turbines. Neither of these problems was the fault of the lubricant, although in the first case the wrong lubricant may have been used. (Using an alternate oil reduced the gear reducer oil temperature by 5° F [-15° C].) Furthermore, the machinery is still in use and was not catastrophically damaged.

Procurement of Lubricants

199. More than 80 brand name products were identified in the survey. Some were used at only one or two installations and were produced by small local companies. In most cases, products of major producers such as Texaco, Exxon, and Chevron were in use. In some cases, the survey form identified only a MIL SPEC, not a product name.

200. The variety of products does not appear to have caused problems in stocking levels and there were no complaints of accidentally using a wrong lubricant due to a large number of lubricants being available. Product selection is based on recommendations of the machine manufacturer, an oil company representative, or recommendations from staff members of Corps operations, engineering, or design sections. In a few cases, foremen or other personnel responsible for maintenance made selections.

201. Procurement also varies. In some cases, bids are accepted from suppliers based on some general specification such as those of a manufacturer or a MIL SPEC. In other cases, bids are accepted for a particular brand name. Several suppliers usually carry the same product and they can bid according to their individual profit requirements. In a few cases, greases appear to have come from government supply sources. In one case, orders were placed for less than a thousand dollars and a sole source was named. Oil that did not meet specifications was received at one installation, which led the district to change its procurement procedures to naming specific brands. Another district reports having requested naphthenic oil but received paraffinic. They ultimately obtained a proprietary product at $3 per gallon (the

services. These services are also available through the Missouri River Division Oil Test Program at the MRD Laboratory, Omaha, NE.

d. It is recommended that strict Corps-wide control not be imposed on the selection and procurement of lubricants. Guidance should merely acquaint personnel with the available options. If a district is satisfied with its current practices, the guidance should not prohibit continuation of the practices. Because Corps installations are spread over a broad range of geographical and climatic conditions, freedom to adjust to local conditions is recommended.

Table 1

Common Additives for Industrial Oils

Rust inhibitors
Oxidation inhibitors
Antifoamants
Demulsifiers
Compounded oil
Antiwear agents
Extreme pressure agents
Pour point depressant
Viscosity index improvers
Tackiness agents

Table 2

Components Used in Grease Formulation

Fluids	Thickeners	Additives
Mineral oil	Sodium soap	Antioxidants
Synthetic oils	Calcium soap	Antiwear additives
Di-esters	Lithium soap	EP additives
Silicones	Aluminum soap	Corrosion inhibitors
Phosphate esters	Barium soap	Friction modifiers
Fluorocarbon	Aluminum complex	Metal deactivators
Fluorinated silicone	Lithium complex	VI improvers
Chlorinated silicone	Bentonite clay	Pour-point depressants
	Silica	Tackiness additives
	Carbon/graphite	Water repellants
	Polyurea	Dyes
	PTFE	Structure modifiers
	Polyethylene	
	Indanthrene dye	
	Phthalocyanine dye	

Table 3

NLGI Grease Classification

NLGI consistency number	Penetration at 77° F (25° C)
000	445 to 475
00	400 to 430
0	355 to 385
1	310 to 340
2	265 to 295
3	220 to 250
4	175 to 205
5	130 to 160
6	85 to 115

Table 4

Percentage of Grease Production by Thickener Type as of 1981*

Thickener	Percent
Soap	
Lithium	59
Calcium	16
Aluminum	8
Sodium	4
Others (mostly barium)	3
Nonsoap	
Inorganic	7
Organic	3
	100

*Reprinted with permission from CRC Handbook of Lubrication (Theory and Practice of Tribology) Vol. II, Copyright 1983, CRC Press, Inc., Boca Raton, FL.

Table 5

Minimum Viscosity at Operating Temperature

Bearing type	SUS	cSt
Radial		
Ball	70	13
Cylindrical roller	100	20
Spherical roller	110	23
Tapered roller	110	23
Thrust		
Ball	150	32
Spherical roller	150	32
Cylindrical roller	160	34
Tapered roller	160	34

Table 6

Types of Lubricant Used With Various Gear Applications

	Gear types				
Lubricant	Spur	Helical	Worm	Bevel	Hypoid
R&O oil (non-EP)	Normal loads	Normal loads	Light loads	Normal loads	Not recommended
EP oil	Heavy or shock loading	Heavy or shock loading	Satisfactory for most applications	Heavy or shock loading	Required for most applications
Compounded oil (about 5% tallow)	Not normally used	Not normally used	Preferred by most gear manufacturers	Not normally used	For light loading only
Heavy-bodied open gear oils	Slow-speed open ONLY	Slow-speed open gearing	Slow-speeds ONLY EP additive desirable	Slow-speeds open gearing	Slow-speeds gearing EP additive required
Grease	Slow-speed open gearing	Slow speed open gearing	Slow-speeds ONLY EP additive desirable	Slow-speeds open gearing	Not recommended

APPENDIX A: VISCOSITY AND GRADE CONVERSIONS

Viscosity ranges for ISO and ASTM systems

ISO viscosity grade	Midpoint kinematic viscosity	Kinematic viscosity limits cSt at 40 °C (104 °F) Min.	Max.	ASTM, Saybolt viscosity number	Saybolt viscosity 100 °F (37.8 °C) Min.	Max.
2	2.2	1.98	2.42	32	34.0	35.5
3	3.2	2.88	3.52	36	36.5	38.2
5	4.6	4.14	5.06	40	39.9	42.7
7	6.8	6.12	7.48	50	45.7	50.3
10	10	9.00	11.0	60	55.5	62.8
15	15	13.5	16.5	75	72	83
22	22	19.8	24.2	105	96	115
32	32	28.8	35.2	150	135	164
46	46	41.4	50.6	215	191	234
68	68	61.2	74.8	315	280	345
100	100	90.0	110	465	410	500
150	150	135	165	700	615	750
220	220	198	242	1,000	900	1,110
320	320	288	352	1,500	1,310	1,600
460	460	414	506	2,150	1,880	2,300
680	680	612	748	3,150	2,800	3,400
1,000	1,000	900	1,100	4,650	4,100	5,000
1,500	1,500	1,350	1,650	7,000	6,100	7,500

Viscosity ranges for AGMA lubricants

Rust and oxidation inhibited gear oils	Viscosity range	Equivalent ISO grade	Extreme pressure Gear lubricants
AGMA lubricant No.	cSt (mm^2/s) at 40 °C		AGMA lubricant No.
1	41.4 to 50.6	46	
2	61.2 to 74.8	68	2 EP
3	90 to 110	100	3 EP
4	135 to 165	150	4 EP
5	198 to 242	220	5 EP
6	288 to 352	320	6 EP
7 Compounded	414 to 506	460	7 EP
8 Compounded	612 to 748	680	8 EP
8A Compounded	900 to 1,100	1,000	8A EP

NOTES: Viscosity ranges for AGMA lubricant numbers will henceforth be identical to those of the ASTM system. Oils compounded with 3 percent to 10 percent fatty or synthetic fatty oils

SAE viscosity grades for engine oils
New Classification (J-300 SEP 80)*

SAE viscosity grade	Viscosity 1/ (cP) at temperature (°C) Max.	Borderline pumping temperature 2/ (°C) Max.	Viscosity 3/ cSt) at 100 °C Min.	Max.
0W	3,250 at -30	-35	3.8	-
5W	3,500 at -25	-30	3.8	-
10W	3,500 at -20	-25	4.1	-
15W	3,500 at -15	-20	5.6	-
20W	4,500 at -10	-15	5.6	-
25W	6,000 at -5	-10	9.3	-
20	-	-	5.6	Less than 9.3
30	-	-	9.3	Less than 12.5
40	-	-	12.5	Less than 16.3
50	-	-	16.3	Less than 21.9

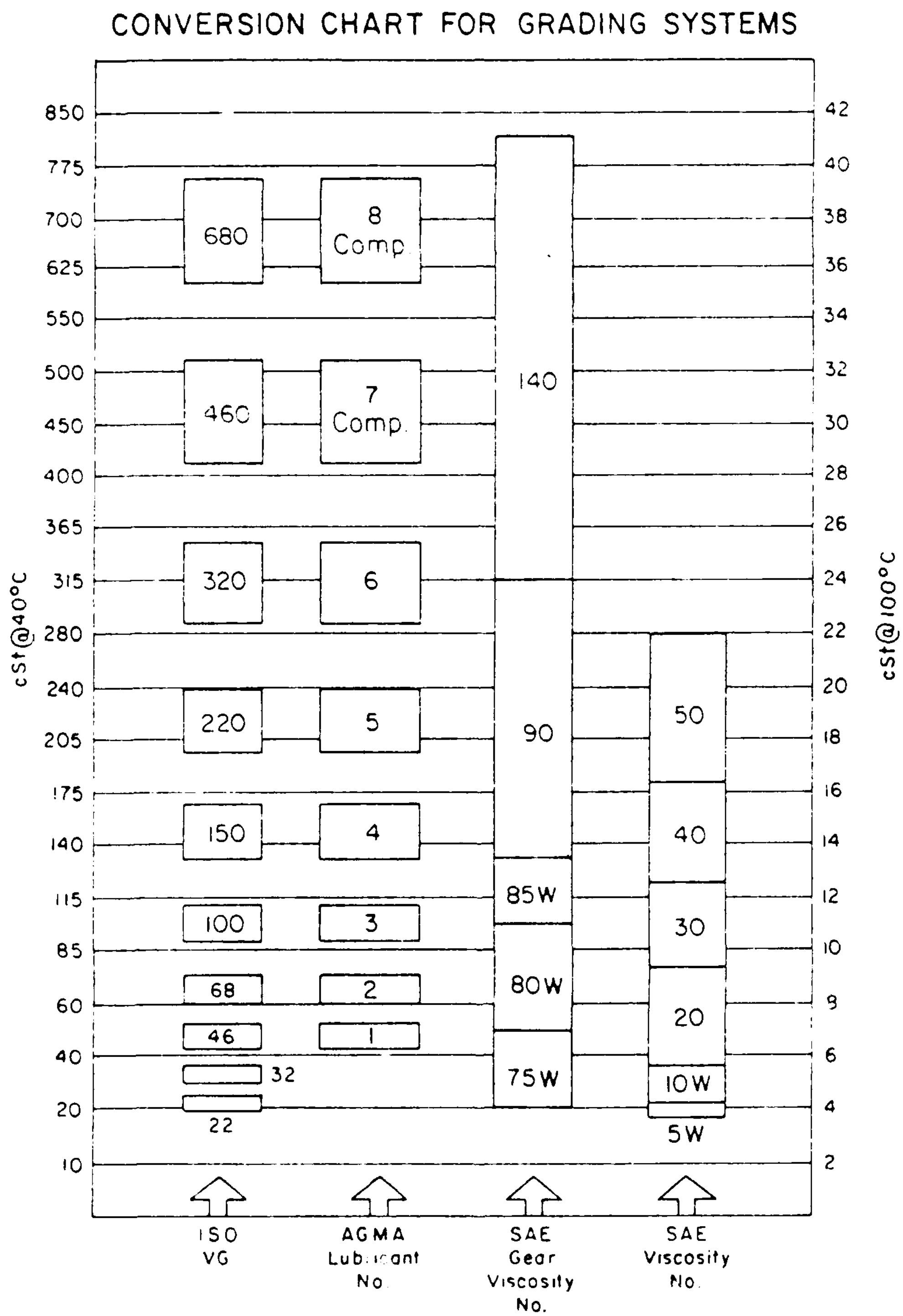
NOTE: 1 cP = 1mPa·s; 1cSt = 1 mm^2/s
1/ ASTM D 2602 (cold cranking simulator)
2/ ASTM D 3829 (mini-rotary viscometer)
3/ ASTM D 445 (Kinematic viscosity)

NLGI grade numbers for greases

NLGI 1/ grade No.	Penetration, ASTM 2/	Description and typical use
000	445-475	Semifluid; centralized systems
00	400-430	Semifluid; centralized systems
0	355-385	Semifluid; centralized systems
1	310-340	Very soft; guns or centralized systems
2	265-295	Soft; guns or centralized systems
3	220-250	Light; grease guns
4	175-205	Medium; pressure guns
5	130-160	Heavy; grease cups
6	85-115	Block; open grease cellars

1/ National Lubricating Grease Institute
2/ Worked (60 strokes), 77 °F (25 °C)

Kinematic (Centistokes)	Saybolt Universal (Seconds)	Kinematic (Centistokes)	Saybolt Universal (Seconds)
1.8	32	96.8	450
2.7	35	102.2	475
4.2	40	107.6	500
5.8	45	118.4	550
7.4	50	129.2	600
8.9	55	140.3	650
10.3	60	151	700
11.7	65	162	750
13.0	70	173	800
14.3	75	183	850
15.6	80	194	900
16.8	85	205	950
18.1	90	215	1,000
19.2	95	259	1,200
20.4	100	302	1,400
22.8	110	345	1,600
25.0	120	388	1,800
27.4	130	432	2,000
29.6	140	541	2,500
31.8	150	650	3,000
34.0	160	758	3,500
36.0	170	866	4,000
38.4	180	974	4,500
40.6	190	1,082	5,000
42.8	200	1,190	5,500
47.2	220	1,300	6,000
51.6	240	1,405	6,500
55.9	260	1,515	7,000
60.2	280	1,625	7,500
64.5	300	1,730	8,000
69.9	325	1,840	8,500
75.3	350	1,950	9,000
80.7	375	2,055	9,500
86.1	400	2,165	10,000
91.5	425		


CONVERSION CHART FOR GRADING SYSTEMS
cSt@40°C
850
775
700
625
550
500
450
400
365
315
280
240
205
175
140
115
85
60
40
20
10
cSt@100°C
42
40
38
36
34
32
30
28
26
24
22
20
18
16
14
12
10
8
6
4
2
680
460
320
220
150
100
68
46
32
22
8 Comp.
7 Comp.
6
5
4
3
2
1
140
90
85W
80W
75W
50
40
30
20
10W
5W
ISO VG
AGMA Lubricant No.
SAE Gear Viscosity No.
SAE Viscosity No.

APPENDIX B: GREASE APPLICATION GUIDE

Properties	Aluminum	Sodium	Calcium-conventional	Calcium-anhydrous	Lithium	Aluminum complex	Calcium complex	Lithium complex	Polyurea
Dropping point (F)	230	325-350	205-220	275-290	350-400	500+	500+	500+	470
Maximum usable temperature (F)	175	250	200	230	275	350	350	350	350
Water resistance	Good to excellent	Poor to fair	Good to excellent	Excellent	Good	Good to excellent	Fair to excellent	Good to excellent	Good to excellent
Work stability	Poor	Fair	Fair to good	Good to excellent	Good to excellent	Good to excellent	Fair to good	Good to excellent	Poor to good
Oxidation stability	Excellent	Poor to good	Poor to excellent	Fair to excellent	Fair to excellent	Fair to excellent	Poor to good	Fair to excellent	Good to excellent
Protection against rust	Good to excellent	Good to excellent	Poor to excellent	Poor to excellent	Poor to excellent	Good to excellent	Fair to excellent	Fair to excellent	Fair to excellent
Pumpability (in centralized system)	Poor	Poor to fair	Good to excellent	Fair to excellent	Fair to excellent	Fair to fair	Poor to fair	Good to excellent	Good to excellent
Oil separation	Good	Fair to good	Poor to good	Good	Good to excellent	Good to excellent	Good to excellent	Good to excellent	Good to excellent
Appearance	Smooth and clear	Smooth to fibrous	Smooth and buttery	Smooth and buttery	Smooth and buttery	Smooth and buttery	Smooth and buttery	Smooth and buttery	Smooth and buttery
Other properties		Adhesive & cohesive	EP grades available	EP grades available	EP grades available	EP grades available	EP grades antiwear inherent	EP grades available	EP grades available
Principal uses 1/	Thread lubricants	Rolling contact economy	General uses for economy	Military multi-service	Multi-service automotive & industrial	Multi-service industrial	Multi-service automotive & industrial	Multi-service automotive & industrial	Multi-service automotive & industrial

1/ Multiservice includes rolling contact bearings, plain bearings, and others.

APPENDIX C: CONOCO OIL FACT SHEETS

Product Guide

REDIND® Oil

Du Pont Code A-101 through A-104

High-Quality Industrial Oil

CONOCO REDIND® Oils constitute a line of high-quality, paraffin-base, foam and rust-inhibited oils. They provide excellent economical service in applications where oxidation-inhibited or extreme pressure oils are not required. The line of CONOCO REDIND® Oils includes 8 regular grades.

CONOCO REDIND® Oils are recommended for, but not limited to, the following applications:

- Lightly loaded speed reducers
- Centrifugal and turbine pumps
- Electrical motors
- Fans and blowers
- Back-up roll bearings in steel and aluminum rolling mills
- Low pressure hydraulic systems
- Air and gas compressors
- Steam and large diesel and gas engine bearings
- General purpose oiling

Customer Benefits

- Economical
- Good natural chemical stability
- Quick separation from water (regular grades)
- Non-foaming
- Protection against rust
- Minimum change in viscosity with temperature change

CONOCO REDIND® Oils are made from high-quality, solvent-refined, and filtered base stocks and contain rust and foam inhibitors.

Package Size

55-gallon drum

CONOCO REDIND® Oil—Typical Specifications

Grade	32	46	68	100	150	220	320	460
ISO/Viscosity Grade	32	46	68	100	150	220	320	460
Gravity, API	31.7	30.8	30.0	29.2	28.6	28.0	27.5	27.0
Flash, °F.	380	400	410	420	435	450	470	540
Pour Point, °F.	-10	-10	-10	10	10	10	10	10
Viscosity:								
SSU @ 100°F.	155	228	340	505	755	1,120	1,630	2,300
SSU @ 210°F.	44	48	55	64	77	95	118	145
cSt @ 40°C.	29-34	43-49	63-73	92-108	138-162	205-235	295-345	420-490
cSt @ 100°C.	5.2	6.6	8.5	11	14.3	18.5	23.7	29.7
Viscosity Index	100	100	98	97	96	96	96	96
ASTM Rust Test, A	Pass							

*ASTM Industrial Fluid Lubricants, Saybolt Viscosity Grade Number

To continue to provide superior quality, Conoco reserves the right to change the composition of its products without notice.

2-50488

CONOCO INC.
HOUSTON, TEXAS

Rev. 6-85

Product Guide

DECTOL® R&O Oil

Premium-Quality Industrial Oils

CONOCO DECTOL® R&O Oils, in eight regular grades, are manufactured from high-quality, solvent-refined, and filtered paraffin-base stocks.

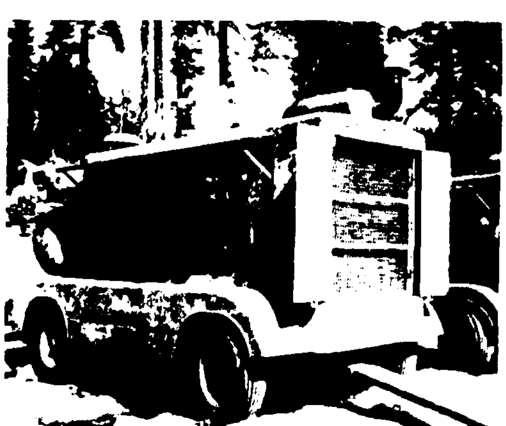
CONOCO DECTOL® R&O Oils contain a well-balanced additive package to provide excellent oxidation resistance, good antiscuff and antiwear properties, and good protection against rust, corrosion, and foam. Oxidation stability at high temperatures reduces the tendency of the oils to "thicken" in service and retards change in acid number.

Customer Benefits

- Effective lubricant for long service life
- Excellent chemical stability
- Minimum effect on most seal materials
- Excellent antiscuff and antiwear properties
- Excellent low temperature properties
- Retains its viscosity over a wide variation in temperatures
- Separates quickly from water
- Nonfoaming
- Superior rust protection to lubricated parts
- Low carbon-forming tendencies in air compressor, diesel, and gas engine cylinders

They have a wide range of service applications and meet the general requirements for oil described as "Turbine Oil Quality." These oils, in the proper grades, are recommended for:

- Air compressors



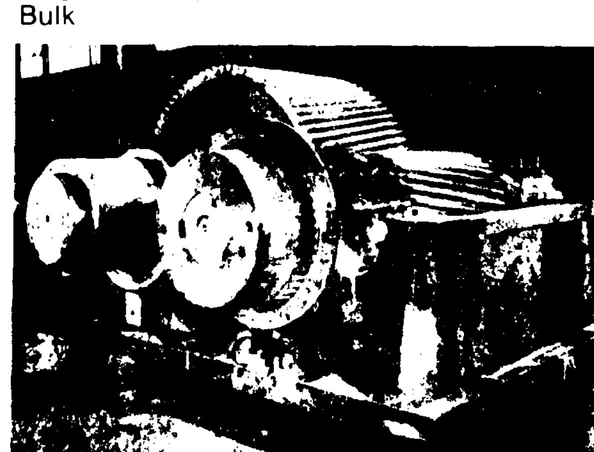
- Gas turbines
- Hydroelectric turbines
- Steam turbines where this quality oil is recommended by the equipment manufacturer
- Hydraulic systems
- Speed reducers
- Plain and antifriction bearings
- Electric motors and generators
- Vacuum pumps
- Centrifugal, turbine, and deep well pumps
- General purpose oiling
- Roller chains
- Oiled couplings

CONOCO DECTOL® R&O Oils meet the requirements of Dennison Specification HF-1. Grade 150 meets the requirements of Military Specification MIL-H-46001C(1). Grade 68 is approved under Cincinnati Milacron Specification P-54. Grade 150 meets the requirements of Cincinnati Milacron Specification P-57.

Even though these oils are highly fortified against oxidation, the correct grades of CONOCO Turbine Oil should be used on equipment handling or exposed to highly reactive gases, such as hydrogen. This applies particularly to hydrogen-cooled generators or compressors.

Package Sizes

55-gallon drum
5-gallon pail (not available for Grades 320 or 460)
Bulk



CONOCO DECTOL* R&O Oil
Product Typicals

ISO Grade	32	46	68	100	150	220	320	460
IVN*	150	215	315	465	700	1000	1500	2150
AGMA No.	—	1	2	3	4	5	6	—
Gravity, API	31.5	30.9	30.3	29.8	29.0	28.5	28.0	27.5
Flash, °F. COC (ASTM D-92) Min.	380	400	440	455	470	490	520	535
Pour Point, °F.	-20	-10	0	5	5	5	5	10
Viscosity:								
SSU @ 100°F.	155	226	340	505	755	1120	1630	2340
SSU @ 210°F.	44	48	55	64	78	95	119	148
cSt @ 40°C.	32	46	68	100	150	220	320	460
cSt @ 100°C.	5.2	6.6	8.5	11.0	14.5	18.7	24.0	30.3
Viscosity Index	100	99	98	98	98	98	98	98
Color, Max. (ASTM D-1500)	2.0	2.5	3.0	5.0	5.5	7.0	7.5	7.5
ASTM Rust Test A&B	Pass							

*ASTM Industrial Fluid Lubricants, Saybolt Viscos 'y Grade Number

Detailed physical health and safety information on this product is available on a Material Safety Data Sheet. This MSDS form may be obtained by writing or calling Conoco Inc., Medical Department, P.O. Box 1267, P140-ST, Ponca City, OK 74603. Phone (405) 767-6000

To continue to provide superior quality, Conoco reserves the right to change the composition of its products without notice

CONOCO Product Guide

Turbine Oil

Premium Quality Turbine Oils

CONOCO Turbine Oils are high-quality, long service-life oils. They are designed to meet the severe chemical stability, antifoam, and antirust requirements of oils for steam, hydraulic, and gas turbines. They also fill the needs of the industry for oil described as "Turbine Oils" or of "Turbine Oil Quality." Turbine oils, in the required grades, are recommended for:

- Steam turbines
- Gas turbines
- Hydro-electric turbines
- Electric motors
- Lightly-loaded hydraulic systems
- Air compressors
- Vacuum and deep well pumps
- Speed reducers
- Lightly-loaded plain and antifriction bearings
- General purpose lubrication

CONOCO Turbine Oils are manufactured in four grades. They are fortified with balanced additives to further improve chemical stability of the oil and extend service life. These oils have had a distinguished service record in industry for many years, yet they are under constant research surveillance to keep them second to none.

Customer Benefits

- Highly-refined, paraffin-base oils—assure maximum chemical stability and minimum effect on seal materials
- High viscosity index—provides low change in viscosity over a given temperature range
- Excellent oxidation stability to give maximum service life
- Separates quickly from water
- Excellent foam resistance—prevents erratic governor operation and assures smooth operation of hydraulic systems
- Superior rust corrosion protection
- Good antiwear qualities
- Low carbon-forming tendencies
- CONOCO Turbine Oil 32 has superb resistance to hydrogen used as a cooling medium in generators
- Exceeds 3,000 hours oxidation stability as measured by ASTM D-943 (Grade 32 only)

Package Sizes

55-gallon drum
5-gallon pail (Grade 32 only)
Bulk

CONOCO Turbine Oil Product Typicals

Grade	32	46	68	100
IVN*	150	215	315	465
ISO/Viscosity Grade	32	46	68	100
AGMA No.	—	1	2	3
Gravity, API	32.1	31.0	30.8	30.3
Flash, °F.	390	410	450	465
Pour Point, °F.	-30	-25	0	5
Viscosity:				
SSU @ 100°F.	155	226	340	505
SSU @ 210°F.	45	49	56	66
cSt @ 40°C.	29-34	43-49	63-73	92-108
cSt @ 100°C.	5.4	6.8	8.7	11.3
Viscosity Index	100	100	99	98
ASTM Rust Test		Pass		
Color, ASTM	2.0	2.5	3.0	5.0
Zinc, P.P.M., Max.	10	10	10	10

*ASTM Industrial Fluid Lubricants, Saybolt Viscosity Grade Number.

Detailed physical, health and safety information on this product is available on a Material Safety Data Sheet. This MSDS form may be obtained by writing or calling Conoco Inc., Medical Department, P.O. Box 1267, P140-ST, Ponca City, OK 74603, Phone (405) 767-6000.

To continue to provide superior quality, Conoco reserves the right to change the composition of its products without notice.

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CONOCO INC.
HOUSTON, TEXAS

5-86

APPENDIX D: PE LIST

Plant Engineering
Magazine's
Exclusive Chart

Interchangeable Lubricants

R. L. MARINELLO, Senior Editor

A reduction in the number of lubricants used in an industrial plant, coupled with an all-out effort to attain the maximum use from each lubricant, should be the main objective of a plant engineering department trying to reduce lubrication costs.

These goals can be accomplished in a number of ways. Savings can be realized by consolidating to fewer types of lubricants, improving purchasing methods, using better quality lubricants for a wider range of machinery, reclaiming used lubricants, and reducing losses from leaks.

Consolidating to fewer types of lubricants should be the first aim of a plant engineering department. The first step is to find out how many types of lubricants the plant uses. Such a study may reveal that individual departments are specifying various lubricants for their own use when a centralized purchasing plan could help reduce the variety by 10 to 30 percent. Several benefits can be realized by stocking fewer lubricants. The chance of lubricators' using the wrong product is reduced, fewer personnel are involved in requisitioning, and inventory can be controlled more effectively.

Plants can consolidate their lubricants and reduce inventory with the help of PLANT ENGINEERING magazine's chart of interchangeable lubricants. The first chart, published in our August 2, 1968, issue, contained the names of 26 suppliers. The chart in this issue, the fifth update, contains the latest information from more than 100 suppliers.

Used properly, the chart can be a valuable reference. It can help the engineering department identify equivalent lubricant products and sources and can serve as a guide for consolidating lubricant stocks. Any plant using more than 20 lubricants is a prime candidate for consolidation. Even if fewer than 20 lubricants are used, further consolidation may be possible.

Some lubrication suppliers might question the advisability of using viscosity as the prime guideline in selecting lubricants. However, viscosity is one of the most important properties of a lubricant, and it is widely used as a general selection guide. Viscosity is specified in sev-

TABLE I

Commonly Used Industrial Lubricant Viscosity Ratings

Plant Engineering Magazine's Designation*	ISO Viscosity Grade	AGMA† Grade No. (approx.)	SAE‡ Viscosity No. (approx.)	SAE Gear Lubricant No. (approx.)	Viscosity, SUS at 210 F (approx.)
32	2	--	--	--	--
60	10	--	--	--	-
105	22	--	--	--	--
150	32	-	10W	75W	40
215	46	1	10	--	43
315	68	2	20	80W	50
465	100	3	30	--	60
700	150	4	40	85W	75
1000	220	5	50	90	95
1500	320	6	60		110
2150	460	7	70	140	130
3150	680	8	--	--	140

*Numbers correspond to viscosity ratings (SUS at 100F + 10 percent) based on ASTM and ASLE recommendations.
†American Gear Manufacturers Association.
‡Society of Automotive Engineers, Inc.

eral ways. The American Society of Lubrication Engineers (ASLE) and the American Society for Testing and Materials (ASTM) have established a standard viscosity scale based on Saybolt Universal Seconds at 100 F. A comparison of the various viscosity ratings that are commonly used in industry is shown in Table I.

The current viscosity classification system is described in "Standard Recommended Practice for Viscosity Systems for Industrial Fluid Lubricants," ASTM D2422-75. It is based on International Standards Organization (ISO) viscosity grade numbers ("Industrial Liquid Lubricants—ISO Viscosity Classification," ISO Standard 3448) and is applicable to fluids ranging in kinematic viscosity from 2 to 1500 cSt at 40 C. Table II lists the 18 ISO viscosity grades and equivalent kinematic viscosity (in cSt at 40 C) and Saybolt viscosity at 104 F (40 C).

The data supplied by the lubricant suppliers merely identify what products fall within the lubricant designation and application. The data do not indicate the quality of each lubricant. Nor is any attempt made to imply what lubricant performance can be expected under a particular set of operating conditions. Lubricant producers and suppliers stress that questions about the effectiveness of a recommended substitution should be answered by the equipment manufacturer or the oil company application engineer.

Outside of special situations, however, most of the lubricant products listed in the chart can be interchanged. And, when this practice is possible, substantial savings can be realized by reducing the number of oils and greases that fall within a specific designation.

Cost savings can also be achieved by improving purchasing practices. The plant should first review present lubrication consumption and the anticipated increase over the next 5 yr. If it uses 8000 gal of a particular lubricant annually, or 6000 gal of two or more lubricants each year, bulk purchasing could be practical. Purchasing lubricants by the drum costs more. Additional costs are involved in handling the drums and in the deposit charged per drum. The deposit charge is now approximately $20 per drum, and it may increase.

Although lubricant costs are going down after the meteoric increases of the past 10 yr, the costs of delivering and handling are not. Rates for delivering lubricant in bulk are lower than rates for vanload shipments of drummed lubricants. The plant engineering department should evaluate the economics of bulk lubricant delivery.

If the plant is using smaller quantities of two or three oils, it may not have the potential for bulk purchasing. But, if a single, better grade of oil will work in place of two or three, the gallonage may increase to the point at which it would be wise to consider bulk purchase.

Many lubricant companies recommend the use of a higher grade lubricant to satisfy the needs of a wider range of machines, including those that normally use lower grade products. Such an approach reduces the number of lubricants as well as the number of suppliers and also cuts down on the space needed for storage.

Another approach is to switch to multipurpose lubricants and greases to lower overall costs and improve machine performance. Multipurpose lubricants and greases are usually of better quality than the products they replace. The improved quality means longer periods of lubricant use, less total volume of lubricant used, reduced application cost, and less downtime for maintenance and repair.

With much sophisticated machinery already in use in many industrial plants, and more expected in the near future, the cost of downtime can be extremely high. The use of better quality lubricants, even at substantially higher prices, can be inexpensive insurance against costly equipment failures. In addition, the high cost of downtime, plus high maintenance labor costs, necessitates the use of quality lubricants to extend the machine's productive capabilities as much as possible.

At one time, oil leaks were a nuisance that was tolerated because of low prices for oil. That is not the case today; the loss of a few drops of oil from loose fittings or worn seals can add up to hundreds of gallons in a year. If only one drop of oil is lost every 10 sec, 39.6 gal will be lost in a year. Should one drop be lost every second, the yearly loss would be 409 gal.

TABLE II. VISCOSITY CONVERSION CHART

ISO Viscosity Grade	Kinematic Viscosity, Centistokes at 40 C (104 F)	Saybolt Viscosity, SUS at 104 F (40 C) (approx.)
2	1.98-2.42	32
3	2.88-3.52	36
5	4.14-5.06	40
7	6.12-7.48	50
10	9.00-11.0	60
15	13,5-16.5	75
22	19.8-24.2	105
32	28.8-35.2	150
46	41.4-50.6	215
68	61.2-74.8	315
100	90.0-110	465
150	135-165	700
220	198-242	1000
320	288-352	1500
460	414-506	2150
680	612-748	3150
1000	900-1100	4650
1500	1350-1650	7000

Many industrial plants are seriously considering installing recycling systems or contracting with refiners offering reclamation service. Waste oils are not now considered hazardous waste and do not fall under the Resource Conservation and Recovery Act administered by the Environmental Protection Agency (EPA). But EPA may classify waste oil as hazardous in the future and write regulations covering its disposal.

Oil does not wear out; it must be discarded only when dust, dirt, carbon, chips, acids, gums, sludge, water, soot, or oxidation products cause the breakdown of unstable constituents. If these products of contamination are properly removed, the oil will be as good as new.

Comparing the lubricants listed on the following pages with those now used may reveal changes that could provide a company with a more efficient, more economical lubrication program.

PLANT ENGINEERING'S CHART OF INTERCHANGEABLE LUBRICANTS

Plant Engineering Designation	ISO Viscosity Grade	Lubricant Type	Viscosity, SUS at 100 F	Advance Engineering	Amalie Refining Co. (Division of Witco Chemical Corp.)
PE-150-A	32	Light Inhibited Hydraulic & Gen. Purpose	135-165	S/1065 Sterling R&O 32	AMA Oil R&O 100 AW
PE-215-A	46	Med. Inhibited Hydraulic & Gen. Purpose	194-236	S/1067 Sterling R&O 46	AMA Oil R&O 200 AW
PE-315-A	68	Med.-Heavy Inhibited Hyd. & Gen. Purpose	284-346	S/1069 Sterling R&O 68	AMA Oil R&O 300 AW
PE-700-A	150	Heavy Inhibited Hydraulic & Gen. Purpose	630-770	S/1071 Sterling R&O 150	AMA Oil R&O 800 AW
PE-150-HP	32	High-Pressure (Anti-Wear) Hydraulic Oil	135-165	S/1064 Sterling R&O AW LP 32	AMA Oil R&O 100 AW
PE-215-HP	46	High-Pressure (Anti-Wear) Hydraulic Oil	194-236	S/1066 Sterling R&O AW LP 46	AMA Oil R&O 200 AW
PE-315-HP	68	High-Pressure (Anti-Wear) Hydraulic Oil	284-346	S/1068 Sterling R&O AW LP 68	AMA Oil R&O 300 AW
PE-FRH-1	—	Fire-Resistant Hyd. Fluid/Synthetic		NR	NR
PE-FRH-2	—	Fire-Resistant Hyd. Fluid/Water-Glycol		NR	NR
PE-FRH-3	—	Fire-Res. Hyd. Fluid/Water-Oil Emulsion		NR	NR
PE-32-B	2	Very Light Spindle Oil (Over 6000 rpm)	29-35	S/1025 Sterling Spindle 2	NR
PE-60-B	10	Light Spindle Oil (3600-6000 rpm)	54-66	S/1027 Sterling Spindle 10	NR
PE-105-B	22	Spindle Oil (Up to 3600 rpm)	95-115	S/1063 Sterling Spindle 22	NR
PE-150-C	32	Light Way Oil	135-165	NR	Bar & Chain Oil
PE-315-C	68	Medium Way Oil	284-346	S/1060 Waylube 68	NR
PE-1000-C	220	Heavy Way Oil	900-1100	S/1062 Waylube 220	NR
PE-700-D	150	Light Gear Oil	630-770	S/1086 Gear Lube EP 150	800 VT Lube
PE-1000-D	220	Medium Gear Oil	900-1100	S/1087 Gear Lube EP 220	SMG 90
PE-2150-D	460	Heavy Gear Oil	1935-2365	S/1089 Gear Lube EP 460	SMG 140
PE-315-E	68	Light Extreme-Pressure Gear Oil	283-347	S/1084 Gea[illegible] P 68	NR
PE-1500-E	320	Heavy Extreme-Pressure Gear Oil	1350-1650	S/1088 Gea[illegible] 320	Tri-Vis Plus
PE-0G-G	—	Cling-Type Gear Shield (Open Gears)		Clingshield 220	NR
PE-GPG-2	—	Gen. Purpose E.P. Lithium-Base Grease	NLGI 2	NR	All Purpose/Moly
PE-MG-2	—	Molybdenum Disulfide E.P. Grease		NR	All Purpose Moly

Plant Engineering Designation	ISO Viscosity Grade	Lubricant Type	Viscosity, SUS at 100 F	American Petroleum and Chemical Corp.	Amoco Oil Co.
PE-150-A	32	Light Inhibited Hydraulic & Gen. Purpose	135-165	Module-Lube 303 Oil	American Ind. Oil #32
PE-215-A	46	Med. Inhibited Hydraulic & Gen. Purpose	194-236	Module-Lube 304 Oil	American Ind. Oil #46
PE-315-A	68	Med.-Heavy Inhibited Hyd. & Gen. Purpose	284-346	Module-Lube 305 Oil	American Ind. Oil #66
PE-700-A	150	Heavy Inhibited Hydraulic & Gen. Purpose	630-770	Module-Lube SD-40 Oil	American Ind. Oil #150
PE-150-HP	32	High-Pressure (Anti-Wear) Hydraulic Oil	135-165	Module-Lube 303 Oil	Rykon Oil #32 or Amoco AW 32
PE-215-HP	46	High-Pressure (Anti-Wear) Hydraulic Oil	194-236	Module-Lube 304 Oil	Rykon Oil #46 or Amoco AW 46
PE-315-HP	68	High-Pressure (Anti-Wear) Hydraulic Oil	284-346	Module-Lube 305 Oil	Rykon Oil #68 or Amoco AW 68
PE-FRH-1	—	Fire-Resistant Hyd. Fluid/Synthetic		PPC Phosphate Ester	Amoco FR Fluid PE
PE-FRH-2	—	Fire-Resistant Hyd. Fluid/Water-Glycol		PPC Water Ester	Amoco FR Fluid WG
PE-FRH-3	—	Fire-Res. Hyd. Fluid/Water-Oil Emulsion		NR	Amoco FR Fluid WO
PE-32-B	2	Very Light Spindle Oil (Over 6000 rpm)	29-35	Module-Lube 290 Oil	Amoco Spindle Oil "A"
PE-60-B	10	Light Spindle Oil (3600-6000 rpm)	54-66	Module-Lube 301 Oil	Amoco Spindle Oil "A"
PE-105-B	22	Spindle Oil (Up to 3600 rpm)	95-115	Module-Lube 302 Oil	Amoco Spindle Oil "C"
PE-150-C	32	Light Way Oil	135-165	Module-Lube SD-10	Waytac Oil #32
PE-315-C	68	Medium Way Oil	284-346	Module-Lube Way Oil 47	Waytac Oil #68
PE-1000-C	220	Heavy Way Oil	900-1100	Module-Lube Way Oil 50	Waytac Oil #220
PE-700-D	150	Light Gear Oil	630-770	Module-Lube SD-40 Oil	American Ind. Oil #150
PE-1000-D	220	Medium Gear Oil	900-1100	Module-Lube SD-50 Oil	American Ind. Oil #220
PE-2150-D	460	Heavy Gear Oil	1935-2365	Module-Lube AG-200 Oil	American Ind. Oil #460
PE-315-E	68	Light Extreme-Pressure Gear Oil	283-347	Module Lube SD-20	Permagear or Amogear EP 68
PE-1500-E	320	Heavy Extreme-Pressure Gear Oil	1350-1650	Module Lube 123 Gear Oil	Permagear or Amogear EP 320
PE-0G-G	—	Cling-Type Gear Shield (Open Gears)		Module Lube Open Gear Grease	Amoco Compound #9
PE-GPG-2	—	Gen. Purpose E.P. Lithium-Base Grease	NLGI 2	Module Lube 7 Plus Grease	Amolith Grease #2 EP
PE-MG-2	—	Molybdenum Disulfide E.P. Grease		Module Lube BRB 77 Grease	Amoco Super Chassis Grease

NR — No recommendation

[1] Does not contain tackiness additives normally found in way lubricants. Formulated to perform as combination hydraulic oil and way lubricant.

[2] To be used where grades 90, 125, and 140 are recommended.

[3] Not lithium base, but equals or exceeds application requirements.

[4] Falls outside specified viscosity range, but meets application requirements.

[5] Not moly grease, but exceeds application requirements.

American Industrial Research Corp.	American Industries, Inc.	The American Lubricants Co. (Alubco)	American Lubricants, Inc.	American Oil & Supply Co.
NR	253 #10 R&O Hyd. Oil	Moly Hyd. Oil #32	160 Hyd. Oil (R&O)	PQ 32
NR	253 #15 R&O Hyd. Oil	Moly Hyd. Oil #46	200 Hyd. Oil (R&O)	PQ 46
NR	253 #20 R&O Hyd. Oil	Moly Hyd. Oil #68	300 Hyd. Oil (R&O)	PQ 68
NR	253 #30 R&O Hyd. Oil	Moly Hyd. Oil #150	650 Hyd. Oil (R&O)	PQ 150
NR	255 #10 AW Hyd. Oil	Moly Hyd. Oil #32	160 AW Hyd. Oil	PQ 32
NR	255 #15 AW Hyd. Oil	Moly Hyd. Oil #46	200 AW Hyd. Oil	PQ 46
NR	255 #20 AW Hyd. Oil	Moly Hyd. Oil #68	300 AW Hyd. Oil	PQ 68
NR	NR	NR	NR	NR
NR	NR	NR	NR	NR
NR	254 FR Hyd. Oil	NR	NR	NR
NR	NR	NR	NR	NR
Rexlube Spindle Oil Light	273 Spindle Oil #1	NR	Spindle Oil 60	PQ Spindle Oil 5
NR	273 Spindle Oil #2	Moly Spindle Oil #22	Spindle Oil 100	PQ Spindle Oil 10
NR	516 Way Lube #10	Moly Special Way Lube #32	NR	NR
Rexlube #20	516 Way Lube #20	Moly Special Way Lube #68	Medium Way Lube	PQ L 30
Rexlube #90	516 Way Lube #50	Moly Special Way Lube #220	Heavy Way Lube	PQ L 90
Rexlube #30	322 Ind. GO #40	Moly Ultra-Tec Gear Lube 80W90	Gear Oil Light	PQ AGMA 4EP
Rexlube #95	322 Ind. GO #90	Moly Ultra-Tec Gear Lube 90	Gear Oil Medium	PQ AGMA 5EP
Rexlube #145	322 Ind. GO #140	Moly Ultra-Tec Gear Lube 140	Gear Oil Heavy	PQ AGMA 7EP
Rexlube #20	325 BIG 7 80W90	Moly Ultra-Tec Gear Lube 80	EP 300 Gear Oil	PQ AGMA 2EP
Rexlube #140	325 BIG 7 85W140	Moly Ultra-Tec Gear Lube 85W140	EP 1500 Gear Oil	PQ AGMA 6EP
Rexlube OGH	336 Open Gear W/Tacky	Bison 88	Super Gear Shield	PQ Open Gear DSL
Rexlube #2	556 MP Bearing Grease	Improved Molyshield	#2 EP Lith Grease	PQ C 4005-2
Rexlube #2	557 A-33 Moly Grease	Moly Deluxe #2	MOS_2 Grease	PQ C 4001-F

Anderson Oil & Chemical Co.	Arco Petroleum Products Co.	Ashland Oil, Inc. Valvoline Oil Co.	Autoline Lubricants Inc.	Baum's Castorine Co., Inc.
Winsor Hyd. Oil 43	Duro 32	ETC (R&O) #15	Terrapin 32 R&O	Tena-Film #150-TH Oil
Winsor Hyd. Oil 45	Duro 46	ETC (R&O) #20	Terrapin 46 R&O	Tena-Film #300-LTH Oil
Winsor Hyd. Oil 52	Duro 68	ETC (R&O) #30	Terrapin 68 R&O	Tena-Film #300-MTH Oil
NR	Duro 117 or 150	ETC (R&O) #70	Terrapin 150 R&O	Tena-Film #400-TH Oil
Winsor Hyd. Oil 43 AW	Duro AW 32	AW Oil #15	Terrapin 32 AW/Super Blue 32 AW	Tena-Film #150-TH Oil
Winsor Hyd. Oil 45 AW	Duro AW 46	AW Oil #20	Terrapin 46 AW/Super Blue 46 AW	Tena-Film #300-LTH Oil
Winsor Hyd. Oil 52 AW	Duro AW 68	AW Oil #30	Terrapin 68 AW/Super Blue 68 AW	Tena-Film #300-MTH Oil
Starlit EM	NR	NR	NR	NR
NR	NR	NR	NR	NR
NR	Duro FR-HD	NR	NR	NR
NR	NR	NR	Spindle Oil 2	NR
Winsor Hi-Speed Spindle Oil	Diamond 7	NR	Spindle Oil 10	NR
Winsor Spindle Oil 4	Diamond 20	ETC (R&O) #10	Spindle Oil 22	Tena-Film #100-TH Oil
NR	Truslide 32	Waylube CHW-15	Way Lube 32	Tena-Film #EP-150-ST Oil
Winsor Way Oil IL	Truslide 68	Waylube W-30	Way Lube 68	Tena-Film #EP-300-ST Oil
NR	Truslide 220	Waylube W-100	Way Lube 220	Tena-Film #EP-1000-ST Oil
Winsor Gear Oil 80	Duro 117 or 150	ETC (R&O) 70	Terrapin 150 AW	Tena-Film #400-TH Oil
Winsor Gear Oil 90	Duro 220	ETC (R&O) 100	Terrapin 220 AW/MP 80W-90	Tena-Film #500-TH Oil
Winsor Gear Oil 140	Rubilene 460	ETC (R&O) 200	Terrapin 460 AW/MP 85W-140	Tena-Film #2500-TH Oil
NR	Pennant NL 68	NR	Industrial EP Gear 68	Tena-Film #EP-300-ST Oil
Hodson Metalcoil 4111	Pennant NL 320	NR	Industrial EP Gear 320	Tena-Film #EP-1400 Oil
Hodson Metalcoil A 185	Jet Lubricant TM	NR	Syncote Open Gear	Tena-Film Moly OG Comp. #0-8470
NR	Litholine HEP 2	Multi-lube Lithium EP Grease	Lithium EP #2	Tena-Film Grease #2 EP
Hodson Nomelt 2254	EP Moly D Grease #2	Special Moly EP Grease	Moly Lith EP #2	Tena-Film Moly Compound #0-23

[6] Straight phosphate ester fluids available in four viscosity grades
[7] Available in range of viscosities
[8] Various ISO grades
[9] Synthetic lubricants
[10] All products formulated from polyalkylene glycol base stocks
[11] Anhydrous product, but water soluble

PLANT ENGINEERING'S CHART OF INTERCHANGEABLE LUBRICANTS

Plant Engineering Designation	ISO Viscosity Grade	Lubricant Type	Viscosity, SUS at 100 F	Bel-Ray Co., Inc.	Benz Oil Co., Inc.
PE-150-A	32	Light Inhibited Hydraulic & Gen. Purpose	135-165	Bel-Ray AW Lube #0	Petralube 32
PE-215-A	46	Med. Inhibited Hydraulic & Gen. Purpose	194-236	Bel-Ray AW Lube #1	Petralube 46
PE-315-A	68	Med.-Heavy Inhibited Hyd. & Gen. Purpose	284-346	Bel-Ray AW Lube #2	Petralube 68
PE-700-A	150	Heavy Inhibited Hydraulic & Gen. Purpose	630-770	Bel-Ray AW Lube #4	Petralube 150
PE-150-HP	32	High-Pressure (Anti-Wear) Hydraulic Oil	135-165	Raylene AW Hyd. Fluid #0	Petraulic 32
PE-215-HP	46	High-Pressure (Anti-Wear) Hydraulic Oil	194-236	Raylene AW Hyd. Fluid #1	Petraulic 46
PE-315-HP	68	High-Pressure (Anti-Wear) Hydraulic Oil	284-346	Raylene AW Hyd. Fluid #2	Petraulic 68
PE-FRH-1	—	Fire-Resistant Hyd. Fluid/Synthetic		Bel-Ray "No Flame" Hyd. Fluid S	NR
PE-FRH-2	—	Fire-Resistant Hyd. Fluid/Water-Glycol		NR	Petraulic Sur-Safe FR-AW
PE-FRH-3	—	Fire-Res. Hyd. Fluid/Water-Oil Emulsion		Bel-Ray "No Flame" Hyd. Fluid E	NR
PE-32-B	2	Very Light Spindle Oil (Over 6000 rpm)	29-35	Raylene EP Spindle Oil Light	NR
PE-60-B	10	Light Spindle Oil (3600-6000 rpm)	54-66	Raylene EP Spindle Oil Med	Petraspeed 600
PE-105-B	22	Spindle Oil (Up to 3600 rpm)	95-115	Raylene EP Spindle Oil Heavy	Petraspeed 1000
PE-150-C	32	Light Way Oil	135-165	Raylene EP Lube #1	NR
PE-315-C	68	Medium Way Oil	284-346	Raylene EP Lube #2	Petac 68
PE-1000-C	220	Heavy Way Oil	900-1100	Raylene EP Lube #5	Petac 220
PE-700-D	150	Light Gear Oil	630-770	Raylene EP Lube #3	Petraulic 150
PE-1000-D	220	Medium Gear Oil	900-1100	Raylene EP Lube #5	Petraulic 220
PE-2150-D	460	Heavy Gear Oil	1935-2365	Raylene EP Lube #7	Petraulic 460
PE-315-E	68	Light Extreme-Pressure Gear Oil	283-347	Bel-Ray 100 Gear Oil #50	Gearol 68
PE-1500-E	320	Heavy Extreme-Pressure Gear Oil	1350-1650	Bel-Ray 100 Gear Oil #90	Gearol 320
PE-0G-G	–	Cling-Type Gear Shield (Open Gears)		Bel-Ray ALC Open Gear Lube #1	Pinion Lube 1500
PE-GPG-2	—	Gen. Purpose E.P. Lithium-Base Grease	NLGI 2	Termalene EP Grease #2	Multi-Service EP #2
PE-MG-2	—	Molybdenum Disulfide E.P. Grease		Molylube 126 EP Grease #2	Moly Alumaplex EP #2

Plant Engineering Designation	ISO Viscosity Grade	Lubricant Type	Viscosity, SUS at 100 F	Certified Laboratories	Champlin Petroleum Co.
PE-150-A	32	Light Inhibited Hydraulic & Gen. Purpose	135-165	HOC 32 or Multoil 5W-20	Hydrol R&O 150
PE-215-A	46	Med. Inhibited Hydraulic & Gen. Purpose	194-236	HOC 46 or Multoil 5W-20	Hydrol R&O 215
PE-315-A	68	Med.-Heavy Inhibited Hyd. & Gen. Purpose	284-346	HOC 68	Hydrol R&O 315
PE-700-A	150	Heavy Inhibited Hydraulic & Gen. Purpose	630-770	HOC 150	Hydrol R&O 700
PE-150-HP	32	High-Pressure (Anti-Wear) Hydraulic Oil	135-165	HOC 32 or HITOP 10W-30	Hydrol AW 150
PE-215-HP	46	High-Pressure (Anti-Wear) Hydraulic Oil	194-236	HOC 46 or HITOP 10W-30	Hydrol AW 215
PE-315-HP	68	High-Pressure (Anti-Wear) Hydraulic Oil	284-346	HOC 68 or HITOP 10W-30	Hydrol AW 315
PE-FRH-1	—	Fire-Resistant Hyd. Fluid/Synthetic		NR	NR
PE-FRH-2	—	Fire-Resistant Hyd. Fluid/Water-Glycol		NR	NR
PE-FRH-3	—	Fire-Res. Hyd. Fluid/Water-Oil Emulsion		NR	NR
PE-32-B	2	Very Light Spindle Oil (Over 6000 rpm)	29-35	NR	NR
PE-60-B	10	Light Spindle Oil (3600-6000 rpm)	54-66	SOC 10	NR
PE-105-B	22	Spindle Oil (Up to 3600 rpm)	95-115	SOC 22	Varitol A
PE-150-C	32	Light Way Oil	135-165	NR	Hydrol AW 150/Varitol A[1]
PE-315-C	68	Medium Way Oil	284-346	WLC 68	Hydrol AW 215/Varitol B[1]
PE-1000-C	220	Heavy Way Oil	900-1100	WLC 220	NR
PE-700-D	150	Light Gear Oil	630-770	HOC 150	Hydrol R&O 700 GL Plus 80W-90
PE-1000-D	220	Medium Gear Oil	900-1100	HOC 220	Hydrol R&O 1000
PE-2150-D	460	Heavy Gear Oil	1935-2365	Certop 85W-140	GL Plus 85W-140
PE-315-E	68	Light Extreme-Pressure Gear Oil	283-347	NR	Champlin Gear Oil 6650
PE-1500-E	320	Heavy Extreme-Pressure Gear Oil	1350-1650	Phenomen-ol 80W-140	NR
PE-0G-G	–	Cling-Type Gear Shield (Open Gears)		NR	NR
PE-GPG-2	—	Gen. Purpose E.P. Lithium-Base Grease	NLGI 2	CCL-24 EP2	Pyrolex[3]
PE-MG-2	—	Molybdenum Disulfide E.P. Grease		Premalube EP2 or CCL-500 EP2	Deluxe With Moly

NR = No recommendation

[1] Does not contain tackiness additives normally found in way lubricants. Formulated to perform as combination hydraulic oil and way lubricant.

[2] To be used where grades 30, 125, and 140 are recommended.

[3] Not lithium base, but equals or exceeds application requirements.

[4] Falls outside specified viscosity range, but meets application requirements.

[5] Not moly grease, but exceeds application requirements.

BP Oil Inc.	Brooks Technology Co.	Cambridge Technical Center	Cato Oil & Grease Co.	Century Hulburt Inc.
Energol HLP 32	**Versalene 600**	**Moly Hyd. 150**	**Pawnee R&O Ind. Oil A.5**	**Huldraulic 150**
Energol HLP 46	**Versalene 610**	**Moly Hyd. 225**	**Pawnee R&O Ind. Oil B**	**Huldraulic 215**
Energol HLP 68	**Versalene 620**	**Moly Hyd. 315**	**Pawnee R&O Ind. Oil C**	**Huldraulic 315**
Energol HLP 150	**Versalene 630**	**Moly Hyd. 700**	**Pawnee R&O Ind. Oil E.5**	**Huldraulic 700**
Energol HLP 32	Versalene 600	Moly Hyd AW 150	Mystik AW AL Hyd Oil 10	Huldraulic 150
Energol HLP 46	Versalene 610	Moly Hyd AW 225	Mystik AW AL Hyd Oil 10	Huldraulic 215
Energol HLP 68	Versalene 620	Moly Hyd AW 315	Mystik AW AL Hyd Oil 20	Huldraulic 315
NR	**NR**	**Saf-T-Lube S**	**NR**	**NR**
NR	**NR**	**Sil-A-Col 200**	**NR**	**NR**
NR	**Versalene 650**	**Saf-T-Lube FR**	**NR**	**Hulsafe 600**
Energol HLP 2	NR	#3 Moly Spindle	Twin Disc Torque Convertor Fluid	NR
Energol HLP 10	NR	#60 Moly Spindle	Mystik Hyd Jack Oil R&O	NR
Energol HLP 22	NR	#1 Moly Spindle	Pawnee R&O Ind Oil A	NR
Energol HP 32[1]	**NR**	**Moly-Way #15**	**Mystik AW/AL Hyd. Oil 10[1]**	**NR**
Energol HP 68-C	**NR**	**Moly-Way #3**	**Mystik Anti-Leak Ind. Oil**	**NR**
Energol HP 220-C	**Slide & Way**	**Moly-Way #9**	**Mystik JT-7 80/90**	**NR**
Energol HLP 150	Lifeguard 55	Moly-Gear 750	Pawnee R&O Ind Oil E.5	Hulbest 70
Energol HLP 220	Lifeguard 70	Moly-Gear 990	Pawnee R&O Ind. Oil F	#32 Gear Oil
Energol HLP 460	Lifeguard 110	Moly-Gear 2250	Pawnee R&O Ind Oil H	#33 Gear Oil
Gearep 80	**Lifeguard 40**	**Moly-Gear EP 325**	**Cato Ind. EP Gear ISO 68**	**Hulbest 50**
Gearep 80W-140[2]	**Lifeguard 90**	**Moly-Gear EP 1500**	**Cato Ind. EP Gear ISO 320**	**#31 Gear Oil**
Gearep OG	Klingfast 85	Moly Open Gear #1000	Ca-Gear 1	#28 Gear Oil
Bearing Gard-2	**Plexalene 726[3]**	**#2 WL Grease**	**Mystik JT-6 Hi-Temp**	**Replex GP-EP**
Bearing Gard-2	Plexalene 725-MO	#2 ML Grease	Moly Lithflex CX All Season	Hullith EP-2 Moly

Chemtool, Inc.	Chevron U.S.A., Inc.	Cities Service Co.	Cling Surface Co., Inc.	Conoco Inc.
Hydro #15	**GST Oil 32**	**Citgo Pacemaker 32**	**HYO Oil 10**	**Dectol R&O Oil 32**
Hydro #25	**GST Oil 46**	**Citgo Pacemaker 46**	**HYO Oil 20**	**Dectol R&O Oil 46**
Hydro #3	**GST Oil 68**	**Citgo Pacemaker 68**	**NR**	**Dectol R&O Oil 68**
Hydro #7	**AW Machine Oil 150**	**Citgo Pacemaker 150**	**NR**	**Dectol R&O Oil 150**
Hydro AW #15	AW Hyd Oil 32	Citgo Pacemaker XD-32 or AW Hyd Oil 32	AW Oil 10	Super Hyd Oil 32
Hydro AW #225	AW Hyd Oil 46	Citgo Pacemaker XD-46 or AW Hyd Oil 46	AW Oil 20	Super Hyd Oil 46
Hydro AW #315	AW Hyd Oil 68	Citgo Pacemaker XD-68 or AW Hyd Oil 68	NR	Super Hyd Oil 68
Syn. Hyd. Fluid (SHF)	**NR**	**NR**	**NR**	**NR**
Chemtool #900	**NR**	**Citgo Glycol FR-40XD**	**NR**	**FC Fluid**
Emulsion Hyd. Fluid (EHF)	**FR Fluid D**	**Citgo Invert FR Fluid**	**NR**	**FR Fluid**
#30 Spindle Oil	NR	NR	NR	TD Torque Fluid[4]
#60 Spindle Oil	AW Machine Oil 10	NR	NR	GP Spindle Oil 7[4]
#100 Spindle Oil	AW Machine Oil 22	NR	NR	Super Hyd Oil 22
#15 Way Lube	**NR**	**NR**	**NR**	**Dectol R&O Oil 32[1]**
#3 Way Lube	**Vistac Oil 68X**	**Citgo SlideRite 68**	**NR**	**HD Way Lube 31**
#9 Way Lube	**Vistac Oil 220X**	**Citgo Sliderite 220**	**NR**	**HD Way Lube 92**
#750 Gear Oil	AW Machine Oil 150	Citgo Pacemaker 150	NR	Dectol R&O Oil 150
#990 Gear Oil	AW Machine Oil 220	Citgo Extra Duty Circ Oil 220	NR	Dectol R&O Oil 220
#2250 Gear Oil	NL Gear Compound 460	Citgo Extra Duty Circ Oil 320	NR	Dectol R&O Oil 460
EP 325 Gear Oil	**NL Gear Compound 68**	**Citgo EP Compound 68**	**APG 80**	**Gear Oil 68**
EP 1500 Gear Oil	**NL Gear Compound 320**	**Citgo EP Compound 320**	**AGG 90**	**Gear Oil 320**
Open Gear #1000	Pinion Grease MS[2]	NR	NR	Cogrease L Lube
White MP Lithium	**Polyurea EP Grease 2**	**Citgo Prem. Lithium EP Grease #2**	**Lithium #2 EP**	**EP Conolith Grease 2**
Moly Lithium Grease	Moly Grease 2	Citgo Extra Range Grease	NR	Super Lube M Grease

[1] Straight phosphate ester fluids available in four viscosity grades
[2] Available in range of viscosities
[3] Various ISO grades
[4] Synthetic lubricants
[5] All products formulated from polyalkylene glycol base stocks
[6] Anhydrous product but water soluble

PLANT ENGINEERING'S CHART OF INTERCHANGEABLE LUBRICANTS

Plant Engineering Designation	ISO Viscosity Grade	Lubricant Type	Viscosity, SUS at 100 F	Convoy Oil Corp.	Cook's Industrial Lubricants, Inc.
PE-150-A	32	Light Inhibited Hydraulic & Gen. Purpose	135-165	Con HY 618	Albavis 8
PE-215-A	46	Med. Inhibited Hydraulic & Gen. Purpose	194-236	Con HY 128	Albavis 10
PE-315-A	68	Med.-Heavy Inhibited Hyd. & Gen. Purpose	284-346	Con HY 138	Albavis 20
PE-700-A	150	Heavy Inhibited Hydraulic & Gen. Purpose	630-770	Con HY 178	Albavis 40
PE-150-HP	32	High-Pressure (Anti-Wear) Hydraulic Oil	135-165	Con HY 618	Albavis 8 Hyd. Oil
PE-215-HP	46	High-Pressure (Anti-Wear) Hydraulic Oil	194-236	Con HY 128	Albavis 10 Hyd. Oil
PE-315-HP	68	High-Pressure (Anti-Wear) Hydraulic Oil	284-346	Con HY 138	Albavis 20 Hyd. Oil
PE-FRH-1	—	Fire-Resistant Hyd. Fluid/Synthetic		Syn Con FR Fluid	NR
PE-FRH-2	—	Fire-Resistant Hyd. Fluid/Water-Glycol		Convoy FR Fluid WG	NR
PE-FRH-3	—	Fire-Res. Hyd. Fluid/Water-Oil Emulsion		Convoy FR Fluid WO	NR
PE-32-B	2	Very Light Spindle Oil (Over 6000 rpm)	29-35	Spinfree XL	NR
PE-60-B	10	Light Spindle Oil (3600-6000 rpm)	54-66	Spinfree L	Spindle Oil 70
PE-105-B	22	Spindle Oil (Up to 3600 rpm)	95-115	Spinfree M	Spindle Oil 115
PE-150-C	32	Light Way Oil	135-165	Waylube 160	Way Lube 6
PE-315-C	68	Medium Way Oil	284-346	Waylube 310	Way Lube 20
PE-1000-C	220	Heavy Way Oil	900-1100	Waylube 1000	Way Lube 50
PE-700-D	150	Light Gear Oil	630-770	Conep 1080	EP Gear Lube 50
PE-1000-D	220	Medium Gear Oil	900-1100	Conep 1090	EP Gear Lube 90
PE-2150-D	460	Heavy Gear Oil	1935-2365	Conep 140	EP Gear Lube 140
PE-315-E	68	Light Extreme-Pressure Gear Oil	283-347	Contrans Light	EP Gear Lube 55
PE-1500-E	320	Heavy Extreme-Pressure Gear Oil	1350-1650	Contrans Heavy	EP Gear Lube 110
PE-0G-G	—	Cling-Type Gear Shield (Open Gears)		Conshield II	Open Gear Compound
PE-GPG-2	—	Gen. Purpose E.P. Lithium-Base Grease	NLGI 2	Convoy Litho EP-2	Universal Pressure Grease
PE-MG-2	—	Molybdenum Disulfide E.P. Grease		Convoy Moly EP-2	NR

Plant Engineering Designation	ISO Viscosity Grade	Lubricant Type	Viscosity, SUS at 100 F	R. W. Eaken, Inc.	E/M Lubricants, Inc.
PE-150-A	32	Light Inhibited Hydraulic & Gen. Purpose	135-165	Fluidvis 32	K 15032
PE-215-A	46	Med. Inhibited Hydraulic & Gen. Purpose	194-236	Fluidvis 46	NR
PE-315-A	68	Med.-Heavy Inhibited Hyd. & Gen. Purpose	284-346	Fluidvis 68	K 15068
PE-700-A	150	Heavy Inhibited Hydraulic & Gen. Purpose	630-770	Fluidvis 150	NR
PE-150-HP	32	High-Pressure (Anti-Wear) Hydraulic Oil	135-165	Premco 32	K 15032
PE-215-HP	46	High-Pressure (Anti-Wear) Hydraulic Oil	194-236	Premco 46	NR
PE-315-HP	68	High-Pressure (Anti-Wear) Hydraulic Oil	284-346	Premco 68	K 15068
PE-FRH-1	—	Fire-Resistant Hyd. Fluid/Synthetic		NR	NR
PE-FRH-2	—	Fire-Resistant Hyd. Fluid/Water-Glycol		NR	NR
PE-FRH-3	—	Fire-Res. Hyd. Fluid/Water-Oil Emulsion		NR	NR
PE-32-B	2	Very Light Spindle Oil (Over 6000 rpm)	29-35	NR	NR
PE-60-B	10	Light Spindle Oil (3600-6000 rpm)	54-66	Eaken Spindle Oil	NR
PE-105-B	22	Spindle Oil (Up to 3600 rpm)	95-115	Premco 22	K 15032[4]
PE-150-C	32	Light Way Oil	135-165	Wayall 60	K 15032
PE-315-C	68	Medium Way Oil	284-346	Wayall 70	K 15068
PE-1000-C	220	Heavy Way Oil	900-1100	Wayall 90	K 400-90
PE-700-D	150	Light Gear Oil	630-770	Fluidvis 150	K 460 85W-140
PE-1000-D	220	Medium Gear Oil	900-1100	Fluidvis 220	K 400 90
PE-2150-D	460	Heavy Gear Oil	1935-2365	Fluidvis 460	K 400 140
PE-315-E	68	Light Extreme-Pressure Gear Oil	283-347	Gear-X 2EP	NR
PE-1500-E	320	Heavy Extreme-Pressure Gear Oil	1350-1650	Gear-X 6EP	K 400 90
PE-0G-G	—	Cling-Type Gear Shield (Open Gears)		NR	K 333
PE-GPG-2	—	Gen. Purpose E.P. Lithium-Base Grease	NLGI 2	NR	K 100[3]
PE-MG-2	—	Molybdenum Disulfide E.P. Grease		NR	K 558

NR — No recommendation

[1] Does not contain tackiness additives normally found in way lubricants. Formulated to perform as combination hydraulic oil and way lubricant.

[2] To be used where grades 90, 125, and 140 are recommended.

[3] Not lithium base, but equals or exceeds application requirements.

[4] Falls outside specified viscosity range, but meets application requirements.

[5] Not moly grease, but exceeds application requirements.

Darmex Industrial Corp.	Davis-Howland Oil Corp.	Delta Resins & Refractories	Dryden Oil Co., Inc.	Du Bois Chemicals
Hyd. 100	Convis OC 150	Deltalene Lite Hyd. Oil #930	Paradene 32 R&O	MPO-10
Hyd. 100/200	Convis OC 200	Deltalene Med. Hyd. Oil #931	Paradene 46 R&O	MPO-20
Hyd. 100/200	Convis OC 300	Deltalene Med-Hvy Hyd. Oil #932	Paradene 68 R&O	MPO-20
Hyd. 100/200	DSL 48	Deltalene Heavy Hyd. Oil #934	Paradene 150 R&O	EGO-80 90 or MPO-30
Hyd. 100	DSL 44	Deltalene Lite Hyd. Oil #930	Paradene 32 AW Blue Hyd. Light	MPO-10
Hyd. 100/200	DSL 45	Deltalene Med. Hyd. Oil #931	Paradene 46 AW Blue Hyd. 10	MPO-20
Hyd. 100/200	DSL 46	Deltalene Med-Hvy Hyd. Oil #932	Paradene 68 AW/Blue Hyd. 20	MPO-20
Darmex NF 50	DSL Syn-Draulic	NR	NR	NR
FR 150 GW	DSL FR-200	NR	NR	NR
FR 100 IE	DSL Hydro-Draulic	NR	NR	Pyro-Safe
SPO L	Conspin 3	NR	Spindle Oil 2	NR
SPO M	Conspin 6	Delta Light Spindle Oil #52B	Spindle Oil 10	NR
SPO H	Conspin 10	NR	Spindle Oil 22	MPO-10
Darmex 10	Way Oil 75	NR	Way Lube 32	MPO-10
Darmex 1050	Way Oil 80	NR	Way Lube 80	MPO-20
Darmex 9140 NM	Way Oil 90	NR	Way Lube 90	EGO-80 90
Darmex 50	Convis OC 750	NR	Paradene 150 W	EGO 80 90 or MPO-30
Darmex 9140	Convis OC 1000	NR	Paradene 220 W APC 80W90	EGO 80 90
Darmex 140	DH 167	Delta IF-5 Gear Compound #257E	Paradene 460 W APC 85W140	EGO 90 140
Darmex GO 1050	Compound 1	NR	EP Gear Lube #2	MPO-20
Darmex 9140	Compound 4	NR	EP Gear Lube #6/ESGL 80W140	EGO-90 140
Darmex 421	Open Gear #2	NR	NR	OGG-H
Darmex 123	AP Lithium EP #2	Delta Lithium Grease 2 #242	Lithium EP #2	TPG
Darmex 123 M	Poly Moly	NR	Moly EP #2	MPG-2[5]

Exxon Co., U.S.A.	Farbest Corp. Allube Products	Filmite Oil Corp.	Gard Corp.	Georgia-Carolina Oil Co.
Teresstic 32 or 33	Hydra-Shield 150	Industrial 150	HydraGard R&O 32	G-C Turbine Oil Light
Teresstic 46	Hydra-Shield 200	Industrial 200	HydraGard R&O 46	G-C Turbine Oil 15
Teresstic 68	Hydra-Shield 300	Industrial 300	HydraGard R&O 68	G-C Turbine Oil Medium
Teresstic 150	Hydra-Shield 800	Industrial 750	HydraGard R&O 150	G-C Turbine Oil Extra Heavy 40
Nuto H 32	Hydra-Shield 150	Industrial 150	HydraGard AW 32	G-C Safety-Press AW Light
Nuto H 46	Hydra-Shield 200	Industrial 200	HydraGard AW 46	G-C Safety-Press AW 15
Nuto H 68	Hydra-Shield 300	Industrial 300	HydraGard AW 68	G-C Safety-Press AW Medium
NR	NR	NR	SafeGard FR Fluid SF	NR
NR	NR	NR	SafeGard FR Fluid WG	NR
3110 FR Hyd. Fluid	Hydra-Shield FR-40	NR	SafeGard FR Fluid WO	NR
NR	NR	NR	SpinGard 2	NR
Spinesstic 10	Lubri-Shield 60	Industrial 50	SpinGard 10	G-C White Star Spindle Oil 60
Spinesstic 22	Lubri-Shield 100	Industrial 100	SpinGard 22	G-C White Star Spindle Oil 100
NR	Lubri-Shield #1	Way Lube 1	Gardway 32	G-C Way Oil Light
Febis K 68	Lubri-Shield #2	Way Lube 3	Gardway 68	G-C Way Oil Medium
Febis K 220	Lubri-Shield #4	Way Lube 9	Gardway 220	G-C Way Oil 90
Teresstic 150	Lubri-Shield #3	Gear Film 70	Gardgear 150	G-C Trans Lube 55
Teresstic 220	Lubri-Shield #4	Gear Film 90	Gardgear 220	G-C Trans Lube 90
Teresstic 460 or Cylesstic TK 460	Lubri-Shield #5	Gear Film 140	Gardgear 460	G-C Trans Lube 140
Spartan EP 68	Lubri-Shield #2	Gear Film 50	Gardgear EP 68	G-C EP Gear Lube 45
Spartan EP 320	Lubri-Shield EP 90 I.G.O.	Gear Film 110	Gardgear EP 320	G-C EP Gear Lube 90
Surett N80k	Lubri-Shield OGL Hvy	Lubriplate Gear Shield	Gardtac 220	G-C Fluid Open Gear Lube 50
Lidok EP 2	Lubri-Shield HTL-2HD	Lubriplate 1200-2	Gard MP Lithium #2	G-C Ben Boy 55-B
Beacon O2	Moly-Shield 2HDM	Lubriplate MO-Lith 2	Gardmoly HiTemp EP	G-C Ben Boy Moly 5

[5] Straight phosphate ester fluids available in four viscosity grades

Available in range of viscosities

Various ISO grades

Synthetic lubricants

All products formulated from polyalkylene glycol base stock

A synthetic product [illegible] water soluble

PLANT ENGINEERING'S CHART OF INTERCHANGEABLE LUBRICANTS

Plant Engineering Designation	ISO Viscosity Grade	Lubricant Type	Viscosity, SUS at 100 F	Getty Refining & Marketing Co. Eastern Region	Central Region	Western Region
PE-150-A	32	Light Inhibited Hydraulic & Gen. Purpose	135-165	Aturbrio 50	Skelvis NH-150	150 AW Hyd.
PE-215-A	46	Med. Inhibited Hydraulic & Gen. Purpose	194-236	Aturbrio 58	Skelvis NH-10	10 AW Hyd.
PE-315-A	68	Med.-Heavy Inhibited Hyd. & Gen. Purpose	284-346	Aturbrio 60	Skelvis NH-20	20 AW Hyd
PE-700-A	150	Heavy Inhibited Hydraulic & Gen. Purpose	630-770	Aturbrio 71	Skelvis NH-40	NR
PE-150-HP	32	High-Pressure (Anti-Wear) Hydraulic Oil	135-165	Aturbrio AW 53	Skelvis MP 150	150 AW Hyd
PE-215-HP	46	High-Pressure (Anti-Wear) Hydraulic Oil	194-236	Aturbrio AW 59	Skelvis MP 10	10 AW Hyd
PE-315-HP	68	High-Pressure (Anti-Wear) Hydraulic Oil	284-346	Aturbrio AW 61	Skelvis MP 20	20 AW Hyd
PE-FRH-1	—	Fire-Resistant Hyd. Fluid/Synthetic		NR	NR	NR
PE-FRH-2	—	Fire-Resistant Hyd. Fluid/Water-Glycol		NR	NR	NR
PE-FRH-3	—	Fire-Res. Hyd. Fluid/Water-Oil Emulsion		NR	NR	NR
PE-32-B	2	Very Light Spindle Oil (Over 6000 rpm)	29-35	NR	NR	NR
PE-60-B	10	Light Spindle Oil (3600-6000 rpm)	54-66	NR	Skelux	NR
PE-105-B	22	Spindle Oil (Up to 3600 rpm)	95-115	Airweave 12	Skelvis 100	NR
PE-150-C	32	Light Way Oil	135-165	Aturbrio 53	Skelvis 150	NR
PE-315-C	68	Medium Way Oil	284-346	Aturbrio 61	Skelvis 20	NR
PE-1000-C	220	Heavy Way Oil	900-1100	Aturbrio 77	Skelvis 50	NR
PE-700-D	150	Light Gear Oil	630-770	Aturbrio 71	Skelvis MP 40	AW Hyd 40
PE-1000-D	220	Medium Gear Oil	900-1100	Apreslube 80	GP Gear 90	EP Gear 90
PE-2150-D	460	Heavy Gear Oil	1935-2365	Apreslube 90	GP Gear 140	EP Gear 140
PE-315-E	68	Light Extreme-Pressure Gear Oil	283-347	NR	GP Gear 80	NR
PE-1500-E	320	Heavy Extreme-Pressure Gear Oil	1350-1650	Apreslube 86	NR	NR
PE-0G-G	—	Cling-Type Gear Shield (Open Gears)		NR	NR	NR
PE-GPG-2	—	Gen. Purpose E.P. Lithium-Base Grease	NLGI 2	Althex MP #2	Getty MPEP #2	Getty MPEP #2
PE-MG-2	—	Molybdenum Disulfide E.P. Grease		Moly EP	Moly EP	Moly EP

Plant Engineering Designation	ISO Viscosity Grade	Lubricant Type	Viscosity, SUS at 100 F	Inter-State Oil Co., Inc.	Jet Lube, Inc.
PE-150-A	32	Light Inhibited Hydraulic & Gen. Purpose	135-165	Resistal EP H-150	NR
PE-215-A	46	Med. Inhibited Hydraulic & Gen. Purpose	194-236	Resistal EP H-215	NR
PE-315-A	68	Med.-Heavy Inhibited Hyd. & Gen. Purpose	284-346	Resistal EP H-315	NR
PE-700-A	150	Heavy Inhibited Hydraulic & Gen. Purpose	630-770	Resistal EP H-700	NR
PE-150-HP	32	High-Pressure (Anti-Wear) Hydraulic Oil	135-165	Resistal EP H-150	NR
PE-215-HP	46	High-Pressure (Anti-Wear) Hydraulic Oil	194-236	Resistal EP H-215	NR
PE-315-HP	68	High-Pressure (Anti-Wear) Hydraulic Oil	284-346	Resistal EP H-315	NR
PE-FRH-1	—	Fire-Resistant Hyd. Fluid/Synthetic		NR	NR
PE-FRH-2	—	Fire-Resistant Hyd. Fluid/Water-Glycol		NR	NR
PE-FRH-3	—	Fire-Res. Hyd. Fluid/Water-Oil Emulsion		NR	NR
PE-32-B	2	Very Light Spindle Oil (Over 6000 rpm)	29-35	Spindle Oil S-32	NR
PE-60-B	10	Light Spindle Oil (3600-6000 rpm)	54-66	Spindle Oil S-60	NR
PE-105-B	22	Spindle Oil (Up to 3600 rpm)	95-115	Spindle Oil S-105	NR
PE-150-C	32	Light Way Oil	135-165	Way-Hyd. Lube W-150	NR
PE-315-C	68	Medium Way Oil	284-346	Way-Hyd. Lube W-315	NR
PE-1000-C	220	Heavy Way Oil	900-1100	Way-Hyd. Lube W-1000	NR
PE-700-D	150	Light Gear Oil	630-770	Ind. Oil H-700	NR
PE-1000-D	220	Medium Gear Oil	900-1100	Ind. Oil H-1000	NR
PE-2150-D	460	Heavy Gear Oil	1935-2365	Ind. Oil H-2150	NR
PE-315-E	68	Light Extreme-Pressure Gear Oil	283-347	Ind. EP Oil 315	NR
PE-1500-E	320	Heavy Extreme-Pressure Gear Oil	1350-1650	Ind. EP Oil 1500	NR
PE-0G-G	—	Cling-Type Gear Shield (Open Gears)		I-S Outside Cog & Gear	Gear Guard WLD OG-M OG-H
PE-GPG-2	—	Gen. Purpose E.P. Lithium-Base Grease	NLGI 2	I-S Preferred MP Grease	CB-2 & 202
PE-MG-2	—	Molybdenum Disulfide E.P. Grease		I-S Moly EP Grease	202 & AP-5 (NLGI-00 0 1 2 3)

NR [illegible]

[illegible]

[illegible]

[illegible]

[illegible] application requirements

Falls outside specified viscosity range but meets application requirements

[illegible] application requirements

Graphite Products Corp.	Gulf Oil Corp.	E. F. Houghton & Co.	Imperial Oil & Grease Co.	International Refining & Manufacturing Co.
NR	Harmony 32	Hydro-Drive HP-150	Molub-Alloy 601	IRMCO HL-14
NR	Harmony 46	Hydro-Drive HP-200	Molub-Alloy 602	IRMCO HL-20
NR	Harmony 68	Hydro-Drive HP-300	Molub-Alloy 603	IRMCO HL-30
NR	Harmony 150	Hydro-Drive HP-750	Molub-Alloy 606	IRMCO HL-69
NR	Harmony 32 AW	Hydro-Drive HP-150	Tribol 771	IRMCO HL-15
NR	Harmony 46 AW	Hydro-Drive HP-200	Tribol 772	IRMCO HL-21
NR	Harmony 68 AW	Hydro-Drive HP-300	Tribol 773	IRMCO HL-31
NR	[6]	Houghto-Safe 1000 Series[7]	NR	NR
NR	FR Fluid G-200	Houghto-Safe 620	NR	NR
NR	FR Fluid	Houghto-Safe 5000 Series	Tribol 587	NR
GP-SO-#40	NR	NR	NR	NR
GP-SO-#70	Gulfspin 10	NR	NR	IRMCO S-6
GP-SO-#100	Gulfspin 22	NR	NR	IRMCO S-10
GP-MWO-305	Harmony 32 AW	Hydro-Drive HP-150	Molub-Alloy MWO 10	IRMCO W-15
GP-MWO-1000	Gulfway 68	NR	Molub-Alloy MWO 20	IRMCO W-31
GP-MWO-1200	Gulfway 220	Sta-Put 370[3]	Molub-Alloy MWO 40	IRMCO W-100
SS-MGO-#80	Harmony 150 or 150D	NR	Molub-Alloy 30	IRMCO HL-70
SS-MGO-#90	Harmony 220	MP Gear Oil 90	Molub-Alloy 40	IRMCO HL-125[4]
SS-MGO-#140	Harmony 460	NR	Molub-Alloy 494	IRMCO HL-215
SS-MGO-80/90	EP Lube HD68	NR	Molub-Alloy 804	IRMCO G2EP
NR	EP Lube HD320	NR	Molub-Alloy 690	IRMCO G6EP
GP-OG (MED)	Premium Lubcote EP	Tenac-M	Molub-Alloy 882 EP-H	NR
GP 33	Gulfcrown Grease EP #2	Cosmolube #2	Molub-Alloy 777-2	IRMCO MP-2
GP 3	Gulflex Moly	Hi-Temp 2409[5]	Molub-Alloy 777-2	IRMCO Moly-Temp

Kendall Refining Co. (Division of Witco Chemical Corp.)	Kent Oil Co. (Moly NRG)	Keystone Div. Pennwalt Corp.	Leahy-Wolf Co.	LubraSystems	Lubrication Analysis, Inc.
Kenoil R&O AW-32	Moly Special Duty #10	KLC-6	Gold Seal Hydrol W	SHO 32 or 1GM 5W-20	Hyd. Oil 150
Kenoil R&O AW-46	Moly Special Duty #15	KLC-5	Gold Seal Hydrol W-H	SHO 46 or 1GM 5W-20	Hyd. Oil 250
Kenoil R&O AW-68	Moly Special Duty #20	KLC-4A	Gold Seal Hydrol S	SHO 68	Hyd. Oil 300
Ken-Tran 080	Moly Special Duty #40	KLC-3	Gold Seal Hydrol 400	SHO 150	Hyd. Oil 700
Kenoil R&O AW-32	Moly Hydro-Servoil #303	KLC-6	Hydrol Master WHD	SHO 32 or MHO 10W-30	Hyd. Oil AW 150
Kenoil R&O AW-46	Moly Hydro-Servoil #304	KLC-5	Hydrol Master WHHD	SHO 46 or MHO 10W-30	Hyd. Oil AW 250
Kenoil R&O AW-68	Moly Hydro-Servoil #305	KLC-4A	Hydrol Master SHD	SHO 68 or MHO 10W-30	Hyd. Oil AW 300
NR	NR	NR	Hydrol Master FR-S	NR	NR
NR	NR	NR	Hydrol Master FR-G	NR	FR-Oil #3
NR	FR Fluid-Invert Emulsion	NR	Hydrol Master FR-FWE	NR	NR
NR	Moly Spindle Oil-Extra Light	NR	NR	NR	Spindle Oil 32
NR	Moly Spindle Oil Light	NR	Lubemaster MAA	SPL 10	Spindle Oil 60
Kenoil 040	Moly Spindle Oil Medium	Spindle Oil #4	Lubemaster MA	SPL 22	Spindle Oil 100
Kenoil 945 EP	Moly Way Oil #10	NR	Tac Master EP 1000	NR	Way Oil 150
NR	Moly Way Oil #20	GP-20	Tac Master EP 2000	WAL 68	Way Oil 300
Kenoil 985 EP	Moly Way Oil #50	GP-30	Tac Master EP 5000	WAL 220	Way Oil 1000
Ken-Tran 080	Moly Gear Oil #89	KLC-3	Gold Seal Hydrol 400	SHO 150	Gear Oil 700
All Oil Gear Lube 85W-90	Moly Gear Oil 90 or 89	1790	Gold Seal Hydrol 500	SHO 220	Gear Oil 900
All Oil Gear Lube 140	Moly Gear Oil 140 or 123	1791	Gold Seal Hydrol 700	MIG 85W-140	Gear Oil 140
NR	Moly Gear Oil RM 300	NR	Industrial EP 2000	NR	Gear Oil EP 300
Three Star Gear Lube	Moly Gear Oil #123	WG-1	Industrial EP 6000	1GO 80W-140	Gear Oil EP 1300
SR 12X	Moly Open Gear Medium	426	Metallic Gear Cote	AOG	Spray Gear Lube
L-426	GP-2 or 7 Plus 2	81 EP LT	Lith Master 200	MML EP2	#2 Grease
L-424	7 Plus 2	NR	Lith Moly Master 200	PCL EP2 or HTL EP2	#2 Moly Grease

[6] Straight phosphate ester fluids available in four viscosity grades
[7] Available in range of viscosities
[8] Various ISO grades
[9] Synthetic lubricants
All products formulated from polyalkylene glycol base stocks
Anhydrous product but water soluble

PLANT ENGINEERING'S CHART OF INTERCHANGEABLE LUBRICANTS

Plant Engineering Designation	ISO Viscosity Grade	Lubricant Type	Viscosity, SUS at 100 F	Lubriplate Div. Fiske Brothers Refining Co.
PE-150-A	32	Light Inhibited Hydraulic & Gen. Purpose	135-165	HO-0
PE-215-A	46	Med. Inhibited Hydraulic & Gen. Purpose	194-236	HO-1
PE-315-A	68	Med.-Heavy Inhibited Hyd. & Gen. Purpose	284-346	HO-2
PE-700-A	150	Heavy Inhibited Hydraulic & Gen. Purpose	630-770	HO-3
PE-150-HP	32	High-Pressure (Anti-Wear) Hydraulic Oil	135-165	HO-0
PE-215-HP	46	High-Pressure (Anti-Wear) Hydraulic Oil	194-236	HO-1
PE-315-HP	68	High-Pressure (Anti-Wear) Hydraulic Oil	284-346	HO-2
PE-FRH-1	—	Fire-Resistant Hyd. Fluid/Synthetic		NR
PE-FRH-2	—	Fire-Resistant Hyd. Fluid/Water-Glycol		NR
PE-FRH-3	—	Fire-Res. Hyd. Fluid/Water-Oil Emulsion		NR
PE-32-B	2	Very Light Spindle Oil (Over 6000 rpm)	29-35	NR
PE-60-B	10	Light Spindle Oil (3600-6000 rpm)	54-66	No. 0
PE-105-B	22	Spindle Oil (Up to 3600 rpm)	95-115	No. 1
PE-150-C	32	Light Way Oil	135-165	No. 1
PE-315-C	68	Medium Way Oil	284-346	No. 3-V
PE-1000-C	220	Heavy Way Oil	900-1100	No. 4
PE-700-D	150	Light Gear Oil	630-770	APG 80
PE-1000-D	220	Medium Gear Oil	900-1100	APG 90
PE-2150-D	460	Heavy Gear Oil	1935-2365	APG 140
PE-315-E	68	Light Extreme-Pressure Gear Oil	283-347	APG 80
PE-1500-E	320	Heavy Extreme-Pressure Gear Oil	1350-1650	APG 140
PE-0G-G	—	Cling-Type Gear Shield (Open Gears)		Gear Shield
PE-GPG-2	—	Gen. Purpose E.P. Lithium-Base Grease	NLGI 2	No. 630-2
PE-MG-2	—	Molybdenum Disulfide E.P. Grease		Mo-Lith No. 2

Plant Engineering Designation	ISO Viscosity Grade	Lubricant Type	Viscosity, SUS at 100 F	McGean-Rohco, Inc. Rohco Div.	Metal Lubricants Co.
PE-150-A	32	Light Inhibited Hydraulic & Gen. Purpose	135-165	McEase AW/AL Polymer Oil 10	Meltran AW 405
PE-215-A	46	Med. Inhibited Hydraulic & Gen. Purpose	194-236	McEase AW/AL Polymer Oil 10	Meltran AW 410
PE-315-A	68	Med.-Heavy Inhibited Hyd. & Gen. Purpose	284-346	McEase AW/AL Polymer Oil 20	Meltran AW 420
PE-700-A	150	Heavy Inhibited Hydraulic & Gen. Purpose	630-770	McEase 75W/90 Polymer Oil	Meltran AW 440
PE-150-HP	32	High-Pressure (Anti-Wear) Hydraulic Oil	135-165	McEase AW/AL Polymer Oil 10	Meltran AW 405
PE-215-HP	46	High-Pressure (Anti-Wear) Hydraulic Oil	194-236	McEase AW/AL Polymer Oil 20	Meltran AW 410
PE-315-HP	68	High-Pressure (Anti-Wear) Hydraulic Oil	284-346	McEase AW/AL Polymer Oil 30	Meltran AW 420
PE-FRH-1	—	Fire-Resistant Hyd. Fluid/Synthetic		NR	NR
PE-FRH-2	—	Fire-Resistant Hyd. Fluid/Water-Glycol		NR	Melsyn FR 200
PE-FRH-3	—	Fire-Res. Hyd. Fluid/Water-Oil Emulsion		NR	NR
PE-32-B	2	Very Light Spindle Oil (Over 6000 rpm)	29-35	McEase AW/AL Polymer Oil 10	NR
PE-60-B	10	Light Spindle Oil (3600-6000 rpm)	54-66	McEase AW/AL Polymer Oil 10	Melspin 5
PE-105-B	22	Spindle Oil (Up to 3600 rpm)	95-115	McEase AW/AL Polymer Oil 10	Melspin 3
PE-150-C	32	Light Way Oil	135-165	McEase AW/AL Polymer Oil 10	Meltac WL-221
PE-315-C	68	Medium Way Oil	284-346	McEase AW/AL Polymer O	Meltac WL-222
PE-1000-C	220	Heavy Way Oil	900-1100	McEase 75W/90 Poly.	Meltac WL-224
PE-700-D	150	Light Gear Oil	630-770	McEase 75W/90 Polymer Gear Oil	Meltran AW 440
PE-1000-D	220	Medium Gear Oil	900-1100	McEase 80W/140 Polymer Gear Oil	Meltran AW 450
PE-2150-D	460	Heavy Gear Oil	1935-2365	NR	Meltran AW 480
PE-315-E	68	Light Extreme-Pressure Gear Oil	283-347	McEase AW/AL Polymer Oil 30	Melcolube 101-CP
PE-1500-E	320	Heavy Extreme-Pressure Gear Oil	1350-1650	McEase 80W/140 Polymer Oil	Melcolube 105-CP
PE-0G-G	—	Cling-Type Gear Shield (Open Gears)		NR	NR
PE-GPG-2	—	Gen. Purpose E.P. Lithium-Base Grease	NLGI 2	McEase MLC-2	Melco PM-2
PE-MG-2	—	Molybdenum Disulfide E.P. Grease		NR	Melcomoly 1433

NR — No recommendation

[1] Does not contain tackiness additives normally found in way lubricants. Formulated to perform as combination hydraulic oil and way lubricant.

[2] To be used where grades [illegible] and 140 are recommended.

[3] Not lithium base, but equals or exceeds application requirements.

[4] Falls outside specified viscosity range, but meets application requirements.

[5] Not moly grease, but exceeds application requirements.

Luscon Industries Corp.	Mainpro, Inc.	Mantek	A. Margolis & Sons Corp.	McCollister & Co. (United Petroleum Corp.)
Hydralube 32	Ultra Shield 5000-10	MHY 32	Silogram TIP 100-15-7	Univis R&O 32
Hydralube 46	NR	MHY 46	Silogram TIP 100-20-7	Univis R&O 46
Hydralube 68	Ultra Shield 5000-20	MHY 68	Silogram TIP 100-30-7	Univis R&O 68
Hydralube 150	Ultra Shield 5000-30	MHY 150	Silogram MP 707	Univis R&O 150
Hydralube XD32 or 32AW	Ultra Shield 5000-10	MHY 32	Silogram TIP 100-15-7	Univis Hyd. AW 32
Hydralube XD46 or 46AW	NR	MHY 46	Silogram TIP 100-20-7	Univis Hyd. AW 46
Hydralube XD68 or 68AW	Ultra Shield 5000-20	MHY 68	Silogram TIP 100-30-7	Univis Hyd. AW 68
Unisafe SF	NR	NR	NR	NR
Unisafe 40XD	NR	NR	Silogram FR Fluid 200	NR
Unisafe WO	NR	NR	Silogram FR Emulsion Fluid	NR
ISOSOLV 30	NR	NR	Silogram LVS 35	NR
Hydralube T-10	NR	MSP 10	Silogram LVS 60	NR
Hydralube T-22	NR	MSP 22	Silogram LVS 100	NR
Waylube 32	US EP Pneumatic 10	NR	Silogram MP 157	Way Oil 32
Waylube 68	US EP Pneumatic 20	MWL 68	Silogram MP 307	Way Oil 68
Waylube 220	US EP Pneumatic 40	MWL 220	Silogram MP 907	Way Oil 220
Hydralube 150	TK-65 80/90	MHY 150	Silogram MP 707	Univis AW 150
Hydralube 220	TK-65 85W/140	MHY 220	Silogram MP 907	Univis AW 220
Hydralube 460	TK-65 140	Manco MP 85W-140	Silogram EP Gear 140	Univis AW 460
EP Compound 68	TK-100 20	NR	Silogram EP Gear 80	EP 68 Gear Comp
EP Compound 320	TK-100 85W/140	Acclaim 80W-140	Silogram EP Gear 90	EP 320 Gear Comp
ALGO M-90	TK-100 140	NR	Silogram Moly Cling	NR
Lithium Grease #2	Pro Lube 600	Staunch EP2	Silogram Centralized EP 2	MP Lithium
Moly Grease #2	Pro Lube 800	Manco Moly EP2 or Elite EP2	Silogram HD MO-Lith	Moly Poly Lithium Complex

Metalworking Lubricants Co.	Mobil Oil Corp.	Moroil Corp.	National Chemsearch	Niagara Lubricant Co., Inc.
Metlube H-100	Mobil DTE Oil Light	R&O 100	HLN-32 or Soludize 5W-20	Nia Vis R&O 32
Metlube H-200	Mobil DTE Oil Med.	R&O 200	HLN-46 or Soludize 5W-20	Nia Vis R&O 46
Metlube H-300	Mobil DTE Oil Med-Hvy	R&O 300	HLN-68	Nia Vis R&O 68
Metlube H-700	Mobil DTE Oil Extra Heavy	R&O 750	HLN-150	Nia Vis R&O 150
Metlube H-150AW	Mobil DTE 24	AW/AL 100	HLN-32 or Enerlex 10W-30	Nia Vis R&O AW 32
Metlube H-200AW	Mobil DTE 25	AW/AL 200	HLN-46 or Enerlex 10W-30	Nia Vis R&O AW 46
Metlube H-300AW	Mobil DTE 26	AW/AL 300	HLN-68 or Enerlex 10W-30	Nia Vis R&O AW 68
Metsafe FR 310	Mobil Pyrogard 53	SNF[8]	NR	NR
Metsafe FR 200	Nyvac FR 200 Fluid	NFH[9]	NR	Nilco Hyrolube 446
Metsafe IFR	Mobil Pyrogard D	NR	NR	NR
99C21	Mobil Velocite Oil #3	NR	NR	NR
Metlube MS	Mobil Velocite Oil #6	Spindle Oil 10	SLN 10	Spindol 10
Metway 100	Mobil Velocite Oil #10	Spindle Oil 22	SLN 22	Spindol 22
Lubemet 150	Mobil Vactra Oil #1	Way Oil 32	NR	Niagara Waylube 32
Lubemet 4868A	Mobil Vactra Oil #2	Way Oil 68	WLN 68	Niagara Waylube 68
Lubemet 4868B	Mobil Vactra Oil #4	Way Oil 220	WLN 220	Niagara Waylube 220
Lubemet 4622D	Mobil DTE Oil Extra Heavy	Indlube 5-150	HLN 150	Aragain 150
Lubemet 4622A	Mobil DTE Oil BB	Indlube 5-220	HLN 220	Aragain 220
Lubemet 4622B	Mobil DTE Oil HH	Indlube 5-460	Gearco 85W/140	Aragain 460
Lubemet 2EP	Mobilgear 626	Indlube 10-68	NR	Aragain EP 68
Lubemet 1500	Mobilgear 632	Indlube 10-320	Effi-cient 80W-140	Aragain EP 320
NR	Mobiltac A	NR	GEX	Gear Shield Spec X9277
Lubemet M1C21	Mobilux EP2	NR	Lube Plus EP2 or Chem-A-Lube NL 660 EP2	Tri-Gard EP #2
NR	NR	NR	Lube Shield EP2	EP Poly Moly #2

[6] Straight phosphate ester fluids available in four viscosity grades
[7] Available in range of viscosities
[8] Various ISO grades
[9] Synthetic lubricants
[10] All products formulated from polyalkylene glycol base stocks
[11] Anhydrous product, but water soluble

PLANT ENGINEERING'S CHART OF INTERCHANGEABLE LUBRICANTS

Plant Engineering Designation	ISO Viscosity Grade	Lubricant Type	Viscosity, SUS at 100 F	NonFluid Oil Corp.	North American Chemical of Texas	The Ore-Lube Corp.
PE-150-A	32	Light Inhibited Hydraulic & Gen. Purpose	135-165	1183	Power Lube 815	00230
PE-215-A	46	Med. Inhibited Hydraulic & Gen. Purpose	194-236	1184	Power Lube 802	00230
PE-315-A	68	Med.-Heavy Inhibited Hyd. & Gen. Purpose	284-346	1185	Power Lube 803	00230
PE-700-A	150	Heavy Inhibited Hydraulic & Gen. Purpose	630-770	NR	Power Lube 807	00230-40
PE-150-HP	32	High-Pressure (Anti-Wear) Hydraulic Oil	135-165	1183	Power Lube 8[illegible]	00230
PE-215-HP	46	High-Pressure (Anti-Wear) Hydraulic Oil	194-236	1184	Power Lube 8[illegible]	00230
PE-315-HP	68	High-Pressure (Anti-Wear) Hydraulic Oil	284-346	1185	Power Lube 803	00230
PE-FRH-1	—	Fire-Resistant Hyd. Fluid/Synthetic		FRHF #68 CI	Fluid Power FR-200	00141
PE-FRH-2	—	Fire-Resistant Hyd. Fluid/Water-Glycol		NR	Fluid Power GHF-20	00265
PE-FRH-3	—	Fire-Res. Hyd. Fluid/Water-Oil Emulsion		NR	Fluid Power 1810	NR
PE-32-B	2	Very Light Spindle Oil (Over 6000 rpm)	29-35	NR	Precision 1924	00227
PE-60-B	10	Light Spindle Oil (3600-6000 rpm)	54-66	300 HSSO	Precision 1925	00106
PE-105-B	22	Spindle Oil (Up to 3600 rpm)	95-115	SP Oil #30	Precision 1926	00107
PE-150-C	32	Light Way Oil	135-165	NR	Lube Way 15	00171
PE-315-C	68	Medium Way Oil	284-346	NR	Lube Way 30	00300
PE-1000-C	220	Heavy Way Oil	900-1100	NR	Lube Way 90	00301
PE-700-D	150	Light Gear Oil	630-770	Gear Pro #4	Gear Guard 60	00214
PE-1000-D	220	Medium Gear Oil	900-1100	Gear Pro #5	Gear Guard 90	00173
PE-2150-D	460	Heavy Gear Oil	1935-2365	Gear Pro #7	Gear Guard 200	00292
PE-315-E	68	Light Extreme-Pressure Gear Oil	283-347	Gear Pro #2/EP	Gear Guard 30	00214
PE-1500-E	320	Heavy Extreme-Pressure Gear Oil	1350-1650	Gear Pro #6/EP	Gear Guard 130	00292
PE-OG-G	—	Cling-Type Gear Shield (Open Gears)		B-576/MS	Gear Cling	10164
PE-GPG-2	—	Gen. Purpose E.P. Lithium-Base Grease	NLGI 2	G-60/EPV	Omegaline 2L	10260[3]
PE-MG-2	—	Molybdenum Disulfide E.P. Grease		Chem-Plex 2/MS	Omegaline 2L-M	10260

Plant Engineering Designation	ISO Viscosity Grade	Lubricant Type	Viscosity, SUS at 100 F	Pillsbury Chemical & Oil Inc.	Rock Valley Oil & Chemical Co., Inc.
PE-150-A	32	Light Inhibited Hydraulic & Gen. Purpose	135-165	Power Lube 815	Trojan 150
PE-215-A	46	Med. Inhibited Hydraulic & Gen. Purpose	194-236	Power Lube 802	Trojan 200
PE-315-A	68	Med.-Heavy Inhibited Hyd. & Gen. Purpose	284-346	Power Lube 803	Trojan 300
PE-700-A	150	Heavy Inhibited Hydraulic & Gen. Purpose	630-770	Power Lube 807	Trojan 750
PE-150-HP	32	High-Pressure (Anti-Wear) Hydraulic Oil	135-165	Power Lube 815	Trojan 160-AW
PE-215-HP	46	High-Pressure (Anti-Wear) Hydraulic Oil	194-236	Power Lube 802	Trojan 210-AW
PE-315-HP	68	High-Pressure (Anti-Wear) Hydraulic Oil	284-346	Power Lube 803	Trojan 315-AW
PE-FRH-1	—	Fire-Resistant Hyd. Fluid/Synthetic		Fluid Power FR-200	NR
PE-FRH-2	—	Fire-Resistant Hyd. Fluid/Water-Glycol		Fluid Power GHF-20	FR Hyd. Fluid WG-200
PE-FRH-3	—	Fire-Res. Hyd. Fluid/Water-Oil Emulsion		Fluid Power 1810	NR
PE-32-B	2	Very Light Spindle Oil (Over 6000 rpm)	29-35	Precision 1924	Rockspin 40
PE-60-B	10	Light Spindle Oil (3600-6000 rpm)	54-66	Precision 1925	Rockspin 60
PE-105-B	22	Spindle Oil (Up to 3600 rpm)	95-115	Precision 1926	Rockspin 100
PE-150-C	32	Light Way Oil	135-165	Lube Way 15	Rockway 150-S
PE-315-C	68	Medium Way Oil	284-346	Lube Way 30	Rockway 300-S
PE-1000-C	220	Heavy Way Oil	900-1100	Lube Way 90	Rockway 1000-S
PE-700-D	150	Light Gear Oil	630-770	Gear Guard 60	Trojan 750
PE-1000-D	220	Medium Gear Oil	900-1100	Gear Guard 90	Trojan 1000
PE-2150-D	460	Heavy Gear Oil	1935-2365	Gear Guard 200	Trojan 2000
PE-315-E	68	Light Extreme-Pressure Gear Oil	283-347	Gear Guard 30	EP Gear Lube S-300
PE-1500-E	320	Heavy Extreme-Pressure Gear Oil	1350-1650	Gear Guard 130	EP Gear Lube S-1600
PE-OG-G	—	Cling-Type Gear Shield (Open Gears)		Gear Cling	Royal Dripless 1000
PE-GPG-2	—	Gen. Purpose E.P. Lithium-Base Grease	NLGI 2	Omegaline 2L	Premium Lithium 2
PE-MG-2	—	Molybdenum Disulfide E.P. Grease		Omegaline 2L-M	Premium Moly-Lith

NR—No recommendation [illegible]

[illegible] Formulated [illegible] combination hydraulic [illegible] and way lubricant.

[illegible] grades [illegible] are recommended.

[3] Not lithium base, but equals or exceeds application requirements.

[4] Falls outside specified viscosity range, but meets application requirements.

[5] Not moly grease, but exceeds application requirements.

Pacer Lubricants, Inc.	Parr Inc.	Pennzoil Products Co.	Phillips Petroleum Co.
Thermal T 32 (150)	NR	AW 32 Hyd. Oil/Penreco Oil 32	Magnus Oil 32
Thermal T 46 (215)	Hydroil EP 82X	AW 46 Hyd. Oil/Penreco Oil 46	Magnus Oil 46
Thermal T 68 (315)	Hydroil EP 83	AW 68 Hyd. Oil/Penreco Oil 68	Magnus Oil 68
Thermal T 150 (700)	Hydroil EP 85	AW 150 Hyd. Oil/Penreco Oil 150	Magnus Oil 150
Power V 32 (150)	Hydroil AW 32	AW 32 Hyd. Oil/Penreco Oil 32	Magnus A Oil 32
Power V 46 (215)	Hydroil AW 46	AW 46 Hyd. Oil/Penreco Oil 46	Magnus A Oil 46
Power V 68 (315)	Hydroil AW 68	AW 68 Hyd. Oil/Penreco Oil 68	Magnus A Oil 68
NR	NR	NR	NR
NR	NR	NR	NR
NR	NR	Maxmul Hyd. Fluid FR	NR
NR	NR	NR	NR
Spindle Oil 70	NR	NR	NR
Spindle Oil 100	NR	AW 22 Hyd. Oil/Penreco Oil 22	Magnus Oil 32
Tru-Slide 150	NR	NR	NR
Tru-Slide 300	Way Lubricant #75	Tableways Lube Medium	NR
Tru-Slide 1000	882 Gear Lube SAE 90	Tableways Lube Heavy	NR
Goltex AGMA 4EP	NR	AW 150 Hyd. Oil/Penreco Oil 150	Magnus Oil 150
Goltex AGMA 5EP	882 Gear Lube SAE 90	AW 220 Hyd. Oil/Penreco Oil 220	Magnus Oil 220
Goltex AGMA 7EP	882 Gear Lube SAE 140	AW 460 Hyd. Oil/Penreco Oil 460	Hector Oil 460 (2000S)
Golden G Gearoyl AGMA 2EP	NR	Maxol EP Gear Oil 68	Philube AP GO 80W
Golden G Gearoyl AGMA 6EP	882 Gear Lube 90 or 140	Maxol EP Gear Oil 320	Philube AP GO 85W-90
NR	Plastigear X	NR	Philsilk D-1 Grease
Synfilm LCX	Litholube EPMP #2	707L Lube/Pennlith EP 712 Lube/MP 705 Lube	Philube EP-2
Lith-O-Mol	Green Gold Moly #2	Molysulfide 704 Lube/TTM 302 Lube	Philube MW Grease

Henry E. Sanson & Sons, Inc.	Schaeffer Manufacturing Co.	Seaboard Industries, Inc.	Sentinel Lubricants Corp.	Shell Oil Co.
No-Gum Hyd. Oil Light	#112 Micron Moly HTC SAE 10	Superior R&O 32	S-10 Hyd. Oil	Turbo 32
No-Gum Hyd. Oil #10	#112 Micron Moly HTC SAE 10	Superior R&O 46	S-10/20 Hyd. Oil	Turbo 46
No-Gum Hyd. Oil #20	#112 Micron Moly HTC SAE 20	Superior R&O 68	S-10/20 Hyd. Oil	Turbo 68
No-Gum Hyd. Oil #40	#112 Micron Moly HTC SAE 40	Superior R&O 150	S-10/50 M.P. Oil	Turbo 150
AW Hyd. Oil 150	#112 Micron Moly HTC SAE 10	Superior A/W Hyd. 32	S-10 Hyd. Oil	Tellus 32
AW Hyd. Oil 215	#112 Micron Moly HTC SAE 10	Superior A/W Hyd. 46	S-10/20 Hyd. Oil	Tellus 46
AW Hyd. Oil 315	#112 Micron Moly HTC SAE 20	Superior A/W Hyd. 68	S-10/20 Hyd. Oil	Tellus 68
Hydra-Safe PE Series[7]	NR	NR	N.F. 65	NR
Hydra-Safe Standard Glycol Series[7]	NR	NR	N.F. 650	NR
Hydra-Mul Premium Emulsion Series[7]	NR	NR	N.F. 750	NR
NR	NR	NR	SPO "L"	NR
No-Gum Spindle Oil VL	NR	Superior Spindle 10	SPO LM	Tellus 10
No-Gum Spindle Oil #9	#119 White Ind. Machine Oil 5	Superior Spindle 22	SPO M	Tellus 22
No-Gum Hyd. Way Lube 150	#203 EP Ind. Machine Oil 10	Superior Waylube 32	S-10	NR
No-Drip Way Lube #297	#203 EP Ind. Machine Oil 20	Superior Waylube 68	S-10/50	Tonna 68
No-Drip Way Lube Heavy	#203 EP Ind. Machine Oil 50	Superior Waylube 220	S-50	Tonna 220
No-Gum Hyd. Oil #40	#209 Moly Univ. Gear Lube 80W-90	Superior EP Compound 150	S-75/80	Turbo 150
No-Gum Lube Oil 550-P	#209 Moly Univ. Gear Lube 80W-90	Superior EP Compound 220	S-90/140	Turbo 220
No-Gum Gear Oil #2100	#209 Moly Univ. Gear Lube 140	Superior EP Compound 460	S-140	Turbo 460
No-Gum EP Gear Oil #315	#209 Moly Univ. Gear Lube 80W-90	Superior EP Compound 68	S-75/80 EP	Omala 68
No-Gum Lube Oil #1500-V	#209 Moly Univ. Gear Lube 80W-90	Superior EP Compound 320	90/140 EP	Omala 320
No-Drip TM	#200 Moly Silver Streak or #224	NR	SOG	Omala H
Syndralube #2	#221 Moly Ultra 800 EP #2	Superior EP Grease B-2	S1 123	Alvania EP 2
Syndralube #2M	#221 Moly Ultra 800 or #260 or #248	Superior Moly Bento Lube	SLM-2	Super Duty

[6] Straight phosphate ester fluids available in four viscosity grades
[7] Available in range of viscosities
[8] Various ISO grades
[9] Synthetic lubricants
[10] All products formulated from polyalkylene glycol base stocks
[11] Anhydrous product but water soluble

PLANT ENGINEERING'S CHART OF INTERCHANGEABLE LUBRICANTS

Plant Engineering Designation	ISO Viscosity Grade	Lubricant Type	Viscosity, SUS at 100 F	Siegel Oil Co.	Southwestern Petroleum Corp.
PE-150-A	32	**Light Inhibited Hydraulic & Gen. Purpose**	135-165	Titon Hyd. Oil #15	Swepco Ind. Oil 702-1
PE-215-A	46	**Med. Inhibited Hydraulic & Gen. Purpose**	194-236	Titon Hyd. Oil #21	Swepco Ind. Oil 702-1
PE-315-A	68	**Med.-Heavy Inhibited Hyd. & Gen. Purpose**	284-346	Titon Hyd. Oil #31	Swepco Ind. Oil 702-2
PE-700-A	150	**Heavy Inhibited Hydraulic & Gen. Purpose**	630-770	Titon Hyd. Oil #51	Swepco Ind. Oil 702-4
PE-150-HP	32	High-Pressure (Anti-Wear) Hydraulic Oil	135-165	Titon AW Hyd. Oil #15	Swepco AW Hyd. Oil 704-10
PE-215-HP	46	High-Pressure (Anti-Wear) Hydraulic Oil	194-236	Titon AW Hyd. Oil #21	Swepco AW Hyd. Oil 704-10
PE-315-HP	68	High-Pressure (Anti-Wear) Hydraulic Oil	284-346	Titon AW Hyd. Oil #31	Swepco AW Hyd. Oil 704-20
PE-FRH-1	—	**Fire-Resistant Hyd. Fluid/Synthetic**		NR	NR
PE-FRH-2	—	**Fire-Resistant Hyd. Fluid/Water-Glycol**		NR	NR
PE-FRH-3	—	**Fire-Res. Hyd. Fluid/Water-Oil Emulsion**		NR	Swepco FR Hyd. Oil 718
PE-32-B	2	Very Light Spindle Oil (Over 6000 rpm)	29-35	NR	NR
PE-60-B	10	Light Spindle Oil (3600-6000 rpm)	54-66	NR	NR
PE-105-B	22	Spindle Oil (Up to 3600 rpm)	95-115	Titon AW Hyd. Oil #15	NR
PE-150-C	32	**Light Way Oil**	135-165	NR	NR
PE-315-C	68	**Medium Way Oil**	284-346	NR	Swepco Gear Lube 201-80/90
PE-1000-C	220	**Heavy Way Oil**	900-1100	NR	Swepco Gear Lube 201/90
PE-700-D	150	Light Gear Oil	630-770	Titon MP Gear Lube #80	Swepco Gear Lube 201-80/90
PE-1000-D	220	Medium Gear Oil	900-1100	Titon MP Gear Lube #90	Swepco Gear Lube 201-90
PE-2150-D	460	Heavy Gear Oil	1935-2365	Titon MP Gear Lube #140	Swepco Gear Lube 201-140
PE-315-E	68	**Light Extreme-Pressure Gear Oil**	283-347	Titon MP Gear Lube #80	Swepco Gear Lube 201-80/90
PE-1500-E	320	**Heavy Extreme-Pressure Gear Oil**	1350-1650	Titon MP Gear Lube #140	Swepco Gear Lube 201-90
PE-OG-G	—	Cling-Type Gear Shield (Open Gears)		NR	Swepco Outside Gear Lube 604
PE-GPG-2	—	**Gen. Purpose E.P. Lithium-Base Grease**	NLGI 2	Titon Plex EP #2	NR
PE-MG-2	—	Molybdenum Disulfide E.P. Grease		Titon HD Moly Grease	Swepco Moly Grease 101

Plant Engineering Designation	ISO Viscosity Grade	Lubricant Type	Viscosity, SUS at 100 F	Standard Oil Co. (Ohio) Boron Oil Co.	Synthetic Oil Corp. of America[9]
PE-150-A	32	**Light Inhibited Hydraulic & Gen. Purpose**	135-165	Energol HL 32	SOC Hyd. 135.3
PE-215-A	46	**Med. Inhibited Hydraulic & Gen. Purpose**	194-236	Energol HL 46	NR
PE-315-A	68	**Med.-Heavy Inhibited Hyd. & Gen. Purpose**	284-346	Energol HL 68	NR
PE-700-A	150	**Heavy Inhibited Hydraulic & Gen. Purpose**	630-770	Energol HLP 150	NR
PE-150-HP	32	High-Pressure (Anti-Wear) Hydraulic Oil	135-165	Energol HLP 32	SOC Hyd. 135.3
PE-215-HP	46	High-Pressure (Anti-Wear) Hydraulic Oil	194-236	Energol HLP 46	NR
PE-315-HP	68	High-Pressure (Anti-Wear) Hydraulic Oil	284-346	Energol HLP 68	NR
PE-FRH-1	—	**Fire-Resistant Hyd. Fluid/Synthetic**		NR	SOC Hyd. 135.3
PE-FRH-2	—	**Fire-Resistant Hyd. Fluid/Water-Glycol**		NR	NR
PE-FRH-3	—	**Fire-Res. Hyd. Fluid/Water-Oil Emulsion**		NR	NR
PE-32-B	2	Very Light Spindle Oil (Over 6000 rpm)	29-35	Energol HLP 2	SOC Artic 30
PE-60-B	10	Light Spindle Oil (3600-6000 rpm)	54-66	Energol HLP 10	NR
PE-105-B	22	Spindle Oil (Up to 3600 rpm)	95-115	Energol HLP 22	NR
PE-150-C	32	**Light Way Oil**	135-165	Energol HLP 32[1]	SOC Longhaul I 135.3
PE-315-C	68	**Medium Way Oil**	284-346	Energol HP-68-C	SOC Longhaul II 285.0
PE-1000-C	220	**Heavy Way Oil**	900-1100	Energol HP-220-C	SOC Longhaul III 901.0
PE-700-D	150	Light Gear Oil	630-770	Energol HLP-150	SOC GO 90
PE-1000-D	220	Medium Gear Oil	900-1100	Energol HLP-220	SOC GO 140
PE-2150-D	460	Heavy Gear Oil	1935-2365	Energol HLP-460	SOC GO 160
PE-315-E	68	**Light Extreme-Pressure Gear Oil**	283-347	Gearep 80	SOC GO 90
PE-1500-E	320	**Heavy Extreme-Pressure Gear Oil**	1350-1650	Gearep 80W-140[2]	SOC GO 140
PE-OG-G	—	Cling-Type Gear Shield (Open Gears)		Gearep OG	SOC Chain Drive
PE-GPG-2	—	**Gen. Purpose E.P. Lithium-Base Grease**	NLGI 2	Bearing Gard-2	SOC Grease I
PE-MG-2	—	Molybdenum Disulfide E.P. Grease		Bearing Gard-2	SOC Grease II

NR—No recommendation

[1] Does not contain tackiness additives normally found in way lubricants. Formulated to perform as combination hydraulic oil and way lubricant.

[2] To be used where grades 90, 125 and 140 are recommended.

[3] Not lithium base, but equals or exceeds application requirements.

[4] Falls outside specified viscosity range, but meets application requirements.

[5] Not moly grease, but exceeds application requirements.

Sta-Lube, Inc.	Stewart-Warner Corp.	D. A. Stuart Oil Co. of America	Sun Refining & Marketing Co.	Superior Industrial Lubricants
Sta-Lube GPO 32	Ind. Oil #"O"	Dasco PS-15 Hyd. Oil	Sunvis 916	#13-32 Hyd. R&O 32
Sta-Lube GPO 46	Ind. Oil #1	Dasco PS-20 Hyd. Oil	Sunvis 921	#13-46 Hyd. R&O 46
Sta-Lube GPO 68	Ind. Oil #2	Dasco PS-30 Hyd. Oil	Sunvis 931	#13-68 Hyd. R&O 68
Sta-Lube GPO 150	HD Hyd. Oil #3	Dasco PS-70 Hyd. Oil	Sunvis 975	#13-150 Hyd. R&O 150
Premium Clear 201	HD Hyd. Oil #"O"	Dasco PS-15 Hyd. Oil	Sunvis 706, 816WR	#14-32 Hyd. R&O AW 32
Premium Clear 202	HD Hyd. Oil #1	Dasco PS-20 Hyd. Oil	Sunvis 747, 821WR	#14-46 Hyd. R&O AW 46
Premium Clear 203	HD Hyd. Oil #2	Dasco PS-30 Hyd. Oil	Sunvis 754, 831WR	#14-68 Hyd. R&O AW 68
NR	NR	Dasco FR 420 Hyd. Fluid	NR	#80-61 FR Synthetic Fluid
NR	NR	Dasco FR 201 Hyd. Fluid	NR	#80-60 FR 40 XD Fluid
NR	NR	Dasco IFR Hyd. Fluid	Sunsafe 450	#80-62 Invert FR Fluid
Moly Shur Spindle Oil X-Light	NR	Dasco 1473	NR	#80-50-2 Super Spin 2
NR	Spindle Oil "A"	NR	Solnus 55	#80-50 Super Spin 10
Moly Shur Spindle Oil Medium	Spindle Oil "A"	Astral 0045	Sunvis 911	#80-52 Super Spin 22
Moly Shur RDW 150	NR	NR	Lubeway 1706	#8-150 Slide-A-Way 32
Moly Shur RDW 315	NR	Sturaco 7140 Way Lube	Sun Way Lube 1180	#8-320 Slide-A-Way 68
Moly Shur RDW 1000	NR	Sturaco 7164 Way Lube	Sun Way Lube 1190	#8-460 Slide-A-Way 220
Clear Shur GO 150	HD Hyd. Oil #4	Sturaco 7134	Sunvis 975, 775	#9001 Mineral Gear Oil Light
Clear Shur GO 220	HD Gear Oil #5	Sturaco 7135	Sunvis 999, 790	#9002 Mineral Gear Oil Medium
Clear Shur GO 460	HD Gear Oil #7	Sturaco 7137	Sunvis 9112	#9003 Mineral Gear Oil Heavy
Moly Shur 2EP 80W	NR	Sturaco 7132	Sunep 1050	#9-68 HD Gear Oil [illegible]
Moly Shur 6EP 940	HD Gear Oil #7	Sturaco 7136	Sunep 1090	#9-320 HD Gear Oil 320
Moly Shur 383 EP OG	Gear Coating "C"	Sturaco 7105	Sunep Compound 250 SP	#8-001 Super HD Bar, Chain, Cable Lube
Clear Shur MPEP #2	MP Lithium	NR	Sun Prestige 742 EP	#8-012 EP Lithium 2 Grease
Moly Shur BRB #2	NR	NR	Sunaplex 882 EPM	#8-011 Moly Lith EP #2 Grease

Tech-Lube Corp.	Texaco Inc.	Texas Refinery Corp.	Tower Oil & Technology Co.	Tri-State Industrial Lubricants, Inc.	Ultrachem Inc.[9]
Off Leak 10 LT	Regal Oil R&O 32	TRC Hyd. Oil SAE 10	Hydroil CC	Hydro-Flo #15	Chemlube 207
Off Leak 10	Regal Oil R&O 46	TRC Hyd. Oil SAE 10	Hydroil D	Hydro-Flo #2	Chemlube 217
Off Leak 20	Regal Oil R&O 68	TRC Hyd. Oil SAE 20	Hydroil EE	Hydro-Flo #3	Chemlube 217
Off Leak 10/50	Regal Oil R&O 150	TRC Hyd. Oil SAE 30	Hydroil F	Hydro-Flo #65	Chemlube 751
TH 10 LT	Rando Oil HD 32	TRC Hyd. Oil SAE 10	Hydroil AW-3	Hydro-Flo AW-15	NR
TH 10	Rando Oil HD 46	TRC Hyd. Oil SAE 10	Hydroil AW-4	Hydro-Flo AW-2	Chemlube 217
TH 20	Rando Oil HD 68	TRC Hdy. Oil SAE 20	Hydroil AW-5	Hydro-Flo AW-3	Chemlube 217
TH PH	Safetytex 46	NR	NR	NR	NR
TH 150 WS	Hyd. Safety Fluid 46	NR	FR Fluid 40	Flo Kool AFH-AW	NR
THW	FR Hydrafluid 82	NR	Safoil #22	NR	NR
TSO 5	NR	NR	Durol AA	#30 Spindle	NR
TSO 10	Spindura Oil 10	NR	Durol A	#60 Spindle	NR
TSO	Spindura Oil 32	TRC Spindle Oil SAE 5	Durol B	#1 Spindle	Chemspin 22
T 10 LT	Rando Oil 32[1]	TRC Rock Drill Oil 10	#15 Way & Gear Lube	Sta-Lube #15	NR
T 20	Way Lube 68	TRC #890 Vari Purpose 75	#47 Way Lube	Sta-Lube #3	NR
T 90	Way Lube 220	TRC #890 Vari Purpose 80/90	#95 Way & Gear Lube	Sta-Lube #9	NR
T 75, 80	Regal Oil R&O 150	TRC #790 Sure Univ. Gear Lube 80	Express Gear Lube F	Gearmate #65	Chemlube 85W-90
T 90	Regal Oil R&O 220	TRC #790 Sure Univ. Gear Lube 90	Express Gear Lube GH	Gearmate #9	Chemlube 140
T 140	Regal Oil 390	TRC #790 Sure Univ. Gear Lube 140	Express Gear Lube J	Gearmate #2100	Chemlube 250
T 20 EP	Meropa 68	TRC #890 Vari Purpose 75	Express Gear Lube EF	Gearmate EP #3	NR
T 90/140 EP	Meropa 320	TRC #890 Vari Purpose 80/90	Express Gear Lube GH	Gearmate EP #1600	Chemlube 250
TG OG	Crater 2X Fluid	TRC Takilube	Kotall	Sta-Lube EP #9	Vischem 373
TG Lithium EP2	Multifak EP 2	TRC Molyplate	Grezall R	GL-85	Vischem 352
TG M2	Molytex EP 2	TRC Moly EP	Grezall ME-1	GL-88	Vischem 350M

[6] Straight phosphate ester fluids available in four viscosity grades
[7] Available in range of viscosities
[8] Various ISO grades
[9] Synthetic lubricants
[10] All products formulated from polyalkylene glycol base stocks
[11] Anhydrous product but water soluble

PLANT ENGINEERING'S CHART OF INTERCHANGEABLE LUBRICANTS

Plant Engineering Designation	ISO Viscosity Grade	Lubricant Type	Viscosity, SUS at 100 F	Union Carbide Corp.[9, 10]
PE-150-A	32	Light Inhibited Hydraulic & Gen. Purpose	135-165	Ucon LB-135XY-26
PE-215-A	46	Med. Inhibited Hydraulic & Gen. Purpose	194-236	Ucon LB-170XY-26
PE-315-A	68	Med.-Heavy Inhibited Hyd. & Gen. Purpose	284-346	Ucon LB-300XY-26
PE-700-A	150	Heavy Inhibited Hydraulic & Gen. Purpose	630-770	Ucon LB-650XY-26
PE-150-HP	32	High-Pressure (Anti-Wear) Hydraulic Oil	135-165	Ucon Hyd. Fluid AW32/WS-34[11]
PE-215-HP	46	High-Pressure (Anti-Wear) Hydraulic Oil	194-236	Ucon Hyd. Fluid AW46
PE-315-HP	68	High-Pressure (Anti-Wear) Hydraulic Oil	284-346	Ucon Hyd. Fluid AW68
PE-FRH-1	—	Fire-Resistant Hyd. Fluid/Synthetic		NR
PE-FRH-2	—	Fire-Resistant Hyd. Fluid/Water-Glycol		Ucon Hydrolube CC-746[7]
PE-FRH-3	—	Fire-Res. Hyd. Fluid/Water-Oil Emulsion		NR
PE-32-B	2	Very Light Spindle Oil (Over 6000 rpm)	29-35	NR
PE-60-B	10	Light Spindle Oil (3600-6000 rpm)	54-66	NR
PE-105-B	22	Spindle Oil (Up to 3600 rpm)	95-115	NR
PE-150-C	32	Light Way Oil	135-165	NR
PE-315-C	68	Medium Way Oil	284-346	NR
PE-1000-C	220	Heavy Way Oil	900-1100	NR
PE-700-D	150	Light Gear Oil	630-770	Ucon Gear Lube 150
PE-1000-D	220	Medium Gear Oil	900-1100	Ucon Gear Lube 220
PE-2150-D	460	Heavy Gear Oil	1935-2365	Ucon LB-1800XH-1
PE-315-E	68	Light Extreme-Pressure Gear Oil	283-347	Ucon Gear Lube 68 EP
PE-1500-E	320	Heavy Extreme-Pressure Gear Oil	1350-1650	Ucon Gear Lube 220EP
PE-0G-G	—	Cling-Type Gear Shield (Open Gears)		NR
PE-GPG-2	—	Gen. Purpose E.P. Lithium-Base Grease	NLGI 2	NR
PE-MG-2	—	Molybdenum Disulfide E.P. Grease		NR

Plant Engineering Designation	ISO Viscosity Grade	Lubricant Type	Viscosity, SUS at 100 F	West Penn Oil Co., Inc.	The White & Bagley Co.
PE-150-A	32	Light Inhibited Hydraulic & Gen. Purpose	135-165	W/P HBM-150	W&B Super Hyd. Oil 150
PE-215-A	46	Med. Inhibited Hydraulic & Gen. Purpose	194-236	W/P HBM-200	W&B Super Hyd. Oil 225
PE-315-A	68	Med.-Heavy Inhibited Hyd. & Gen. Purpose	284-346	W/P HBM-300	W&B Super Hyd. Oil 300
PE-700-A	150	Heavy Inhibited Hydraulic & Gen. Purpose	630-770	W/P HBM-650	W&B Super Hyd. Oil 600
PE-150-HP	32	High-Pressure (Anti-Wear) Hydraulic Oil	135-165	W/P AWH-150	W&B Super Hyd. Oil 150
PE-215-HP	46	High-Pressure (Anti-Wear) Hydraulic Oil	194-236	W/P AWH-200	W&B Super Hyd. Oil 225
PE-315-HP	68	High-Pressure (Anti-Wear) Hydraulic Oil	284-346	W/P AWH-300	W&B Super Hyd. Oil 300
PE-FRH-1	—	Fire-Resistant Hyd. Fluid/Synthetic		NR	NR
PE-FRH-2	—	Fire-Resistant Hyd. Fluid/Water-Glycol		NR	NR
PE-FRH-3	—	Fire-Res. Hyd. Fluid/Water-Oil Emulsion		NR	NR
PE-32-B	2	Very Light Spindle Oil (Over 6000 rpm)	29-35	W/P Westspin #3	W&B Precision Spindle Oil 45
PE-60-B	10	Light Spindle Oil (3600-6000 rpm)	54-66	W/P Westspin #6	W&B Universal Spindle Oil 60
PE-105-B	22	Spindle Oil (Up to 3600 rpm)	95-115	W/P Westspin #10	W&B Universal Spindle Oil 100
PE-150-C	32	Light Way Oil	135-165	W/P Pennway Light	W&B Light Hyd. & Way Lube
PE-315-C	68	Medium Way Oil	284-346	W/P Pennway Med.	W&B Med. Way Lube
PE-1000-C	220	Heavy Way Oil	900-1100	W/P Pennway Heavy	W&B Heavy Way Lube
PE-700-D	150	Light Gear Oil	630-770	W/P Mineral Gear Light	W&B Hyaline Oil H
PE-1000-D	220	Medium Gear Oil	900-1100	W/P Mineral Gear Med	W&B Hyaline Oil J
PE-2150-D	460	Heavy Gear Oil	1935-2365	W/P Mineral Gear Heavy	W&B Hyaline Oil L
PE-315-E	68	Light Extreme-Pressure Gear Oil	283-347	W/P APG 80	W&B EP Gear Oil SAE 80-W
PE-1500-E	320	Heavy Extreme-Pressure Gear Oil	1350-1650	W/P APG 96	W&B EP Gear Oil SAE 90
PE-0G-G	—	Cling-Type Gear Shield (Open Gears)		W/P OGS	Oilzum Open Gear Lube
PE-GPG-2	—	Gen. Purpose E.P. Lithium-Base Grease	NLGI 2	W/P Lith #2 EP	Oilzum Multi-Purpose Lube
PE-MG-2	—	Molybdenum Disulfide E.P. Grease		W/P Moly Lith #2 EP	Oilzum Moly Lube

NR — No recommendation

[1] Does not contain tackiness additives normally found in way lubricants. Formulated to perform as combination hydraulic oil and way lubricant.

[2] [illegible] be used where grades [illegible] and [illegible] are recommended.

[3] Not lithium base, but equals or exceeds application requirements.

[4] Falls outside specified viscosity range, but meets application requirements.

[5] Not moly grease, but exceeds application requirements.

Union Oil Co. of California Western Region	Eastern Region	United Refining Co.	U.S. Industrial Lubricants	Viscosity Oil Co.	Wallover Oil Co.
Turbine Oil 32	**Unax RX 32**	**Emblem R&O 150**	**Polymer 141**	**PTO 32 AZ**	**Woco Turbine & Hyd. Oil 150**
Turbine Oil 46	**Unax RX 46**	**Emblem R&O 200**	**Polymer 141**	**PTO 46 AZ**	**Woco Turbine and Hyd. Oil 200**
Turbine Oil 68	**Unax RX 68**	**Emblem R&O 300**	**Polymer 141**	**PTO 68 AZ**	**Woco Turbine & Hyd. Oil 300**
Turbine Oil 150	**Unax RX 150**	**Emblem R&O 650**	**Polymer 142**	**PTO 150 AZ**	**Woco Turbine & Hyd. Oil 700**
Unax AW 32	Unax AW 32	Emblem AW-160	Polymer 141	PTO 32 AZ	Woco Hyd. Oil AW-150
Unax AW 46	Unax AW 46	Emblem AW-200	Polymer 141	PTO 46 AZ	Woco Hyd. Oil AW-200
Unax AW 68	Unax AW 68	Emblem AW-300	Polymer 141	PTO 68 AZ	Woco Hyd. Oil AW-300
NR	**NR**	**NR**	**FR-2**	**NR**	**NR**
NR	**NR**	**NR**	**WGF 200/300**	**NR**	**NR**
FR Fluid	**FR Fluid**	**NR**	**FR-WO**	**NR**	**NR**
NR	NR	NR	Polymer 140	Vertex 40	Wocospin 35
NR	NR	Emblem R&O 55	Polymer 140	S-6	Wocospin 57
Turbine Oil 22	Unax 22	Emblem R&O 100	Polymer 140	S 10	Wocospin [illegible]
Way Oil HD 32	**NR**	**Emblem Powerway 150**	**Polymer 141**	**Visway 1**	**Woco AWT-150**
Way Oil HD 68	**Way Oil HD 68**	**Emblem Powerway 350**	**Polymer 142**	**Visway 2**	**Woco AWT-300**
Way Oil HD 220	**Way Oil HD 220**	**Emblem Powerway 900**	**USL-90**	**Visway 4**	**Woco AWT-1000**
Unax 150	Unax 150	United Premium 40	USL-80	PTO 150 AZ	Woco Regular Gear Oil [illegible]
Unax 220	Unax 220	Emblem Mineral Gear 90	USL-90	PTO 220 AZ	Woco Regular Gear Oil [illegible]
Unax 460	Unax 460	Emblem Mineral Gear 140	USL-140	PTO 460	Woco Regular Gear Oil [illegible]
Extra Duty NL 2 EP	**Extra Duty NL 2 EP**	**Emblem APG 80**	**USL-30**	**Rex 2 EP**	**Woco EP Gear Oil 50**
Extra Duty NL 6 EP	**Extra Duty NL 6 EP**	**Emblem APG 95**	**USL-90/140**	**Rex 6 EP**	**Woco EP Gear Oil 105**
Gearite Heavy	Gearite Heavy	Emblem Open Gear	Cling-Tac	Outside Gear Lube	NR
Unoba EP #2	**Unoba EP #2**	**Emolube 302 EP**	**Poly-Temp**	**EP Lith #2**	**Woco EP Lithium Grease #2**
Unoba Moly HD #2	Unoba Moly HD #2	Emolube 292	Moly X-D	HD Moly #2	Woco Moly [illegible] Grease #2

White & Begley of Michigan, Inc.	Arthur C. Withrow Co.	Wylie Lubricants CW Petroleum and Chemical, Inc.	O. F. Zurn Co.
Penn-Mar Super Hyd. Oil 150	**S Light Lube Oil**	Turbinol 32	Zurnpreem 15A
Penn-Mar Super Hyd. Oil 225	**S Med. Lube Oil**	Turbinol 46	Zurnpreem 21A
Penn-Mar Super Hyd. Oil 300	**S Med-Hvy. Lube Oil**	Turbinol 68	Zurnpreem 30A
Penn-Mar Super Hyd. Oil 600	**S Extra Heavy Lube Oil**	Turbinol 150	Zurnpreem 70A
Penn-Mar Super Hyd. Oil 150	H Light AW Hyd. Oil	Turbinol-AW 32	Zurnpreem 15A
Penn-Mar Super Hyd. Oil 225	H Med. AW Hyd. Oil	Turbinol-AW 46	Zurnpreem 21A
Penn-Mar Super Hyd. Oil 300	H Med-Hvy. AW Hyd. Oil	Turbinol-AW 68	Zurnpreem 30A
NR	**NR**	Turbinol-FR Fluid	**NR**
NR	**Withrow 841 Safety Hyd. Fluid**	Turbinol-FR-G Fluid	**NR**
NR	**NR**	Turbinol-FR-E Fluid	**NR**
Penn-Mar R&O Spindle Oil 45	NR	NR	Zurnpreem 3A
Penn-Mar R&O Spindle Oil 60	H-60 AW Hyd. Oil	Turbinol-S 10	Zurnpreem 6A
Penn-Mar R&O Spindle Oil 100	H Light AW Hyd. Oil	Turbinol-S 22	Zurnpreem 10A
Penn-Mar Light Hyd. & Way Lube	**Withrow 625-150 Way Oil**	Turbinol-Way 32	**Zurn Waylube 15**
Penn-Mar Med. Way Lube	**Withrow 625-300 Way Oil**	Turbinol-Way 68	**Zurn Waylube 80**
Penn-Mar Heavy Way Lube	**Withrow 625-900 Way Oil**	Turbinol-Way 220	**Zurn Waylube 90**
Penn-Mar EP Gear Oil #2	Withrow EP-4 Gear Oil	Turbinol-Gear 150	Zurnpreem 70A
Dart-Lube K	Withrow EP-5 Gear Oil	Turbinol-Gear 220	Zurnpreem 95A
Penn-Mar EP Gear Oil #4	AP Gear Oil SAE 140	Turbinol-Gear 460	Zurnpreem 140A
Penn-Mar EP Gear Oil #1	**NR**	Turbinol-Gear EP 68	**Zurn EP Lube 68**
Penn-Mar EP Gear Oil #3	**AP Gear Oil SAE 90**	Turbinol-Gear EP 320	**Zurn EP Lube 320**
Penn-Mar Open Gear Shield 800	NR	Turbinol Open Gear G	Zurn Open Gear Lube
Penn-Mar Kote Z-1120-2	**Lithium EP #2 Grease**	Turbinol EP 2 Grease	**Zurn MD #2 EP Grease**
Penn-Mar Kote Z-1420-2	Moly-Dee Multi-Purpose Grease	Turbinol SD Grease	Zurn MD #2-Moly Grease

6 Straight phosphate ester fluids available in four viscosity grades
7 Available in range of viscosities
8 Various ISO grades
9 Synthetic lubricants
10 All products formulated from polyalkylene glycol base stocks
11 Anhydrous product but water soluble

APPENDIX E: AGMA LUBRICATION SPECIFICATIONS

Table E1. Viscosity ranges for AGMA lubricants

R&O inhibited gear oils (AGMA lubricant NO.)	Viscosity range [cSt (mm^2/s) at 40 °C] 1/	Equivalent ISO grade 2/	FP gear lubricants (AGMA lubricant No.) 3/	Viscosities of AGMA former system (SSU at 100 °F) 4/
1	41.4-50-6	46		193-235
2	61.2-74.8	68	2 EP	284-347
3	90-110	100	3 EP	417-510
4	135-165	150	4 EP	626-765
5	198-242	220	5 EP	918-1,122
6	288-352	320	6 EP	1,335-1,632
7 Comp	414-506	460	7 EP	1,919-2,346
8 Comp 5/	612-748	680	8 EP	2,837-3,467
8A Comp 5/	900-1,100	1,000	8A EP	4,171-5,098

Note: Viscosity ranges for AGMA lubricant numbers will henceforth be identical to those of the ASTM system (footnote 1).

1/ "Viscosity system for Industrial Fluid Lubricants," ASTM 2422; also British Standards Institute, B.S. 4231.
2/ "Industrial Liquid Lubricants - ISO Viscosity Classification," International Standard, ISO 3448.
3/ Extreme pressure lubricants should be used only when recommended by the gear drive manufacturer.
4/ AGMA 250.03, May 1972 and AGMA 251.02, November 1974.
5/ Oils marked Comp are compounded with 3-10 percent fatty or synthetic fatty oils.

From Standard AGMA 250.04, Lubrication of Industrial Enclosed Gear Drives, American Gear Manufacturers Association, Arlington, Virginia, 1974.

Table E2

AGMA lubricant number recommendations for enclosed helical, herringbone, straight bevel, spiral bevel, and spur gear drives

Low-speed center distance		AGMA lubricant No. 2/ 3/ Ambient temp 4/	
Type of unit 1/	(Size of unit)	-10-+10 °C (15-50 °F) 5/	10-50 °C (50-125 °F)
Parallel shaft Up to 200 mm	(single reduction) (to 8 in.) 6/	2-3	3-4
Over 200 mm up to 500 mm	(8 to 20 in) 6/	2-3	4-5
Over 500 mm	(Over 20 in)	3-4	4-5
Parallel shaft	(Double reduction)		
Up to 200 mm	(To 8 in) 6/	2-3	3-4
Over 200 mm	(Over 8 in)	3-4	4-5
Parallel shaft	(Triple reduction)		
Up to 200 mm	(To 8 in)	2-3	3-4
Over 200 mm, up to 500 mm	(8 to 20 in) 6/	3-4	4-5
Over 500 mm	(Over 20 in) 6/	4-5	5-6
Planetary gear units	(Housing diameter)		
Up to 400 mm	(To 16 in) OD	2-3	3-4
Over 400 mm	(Over 16 in) OD	3-4	4-5
Straight or spiral bevel gear units Cone distance up to 300 mm	(T. 12 in) 6/	2-3	4-5
Cone distance over 300 mm	(Over 12 in) 6/	3-4	5-6
Gear motors and shaft-mounted units		2-3	4-5
High-speed units 7/		1	2

1/ Drives incorporating overrunning clutches as backstopping devices should be referred to the gear drive manufacturer as certain types of lubricants may adversely affect clutch performance.
2/ Ranges are provided to allow for variations in operating conditions such as surface finish, temperature rise, loading, speed, etc.
3/ AGMA viscosity number recommendations listed above refer to R&O gear oils shown in table 2, EP gear lubricants in the corresponding viscosity grades may be substituted where deemed necessary by the gear drive manufacturer.
4/ For ambient temperatures outside the ranges shown, consult the gear manufacturer. Some synthetic oils have been used successfully for high- or low-temperature applications.
5/ Pour point of lubricant selected should be at least 5 °C lower than the expected minimum ambient starting temperature. If the ambient starting temperature approaches lubricant pour point, oil sump heaters may be required to facilitate starting and ensure proper lubrication.
6/ Inch unit as shown are approximations.
7/ High-speed units are those operating at speeds above 3,600 rpm or pitch line velocities above 25 m/s (5,000 fpm) or both. Refer to Standard AGMA 421, Practice for High Speed Helical and Herringbone Gear Units, for detailed lubrication recommendations.

From Standard AGMA 250.04, Lubrication of Industrial Enclosed Gear Drives, American Gear Manufacturers Association, Arlington, Virginia, 1974.

Table E3

AGMA lubricant number recommendations for enclosed cylindrical, and double-enveloping worm gear drives

Type (worm gear drive)	Worm speed up to (rpm)	AGMA lubricant no. 1/ Ambient temperature 2/ -10 to +10 °C (15 to 50 °F) 3/	AGMA lubricant no. 1/ Ambient temperature 2/ 10 to 50 °C (50 to 125 °F) 3/	Worm speed above (rpm) 4/	AGMA lubricant no. 1/ Ambient temperature 2/ -10 to +10 °C (15 to 50 °F) 3/	AGMA lubricant no. 1/ Ambient temperature 2/ 10 to 50 °C (50 to 125 °F) 3/
Cylindrical worm 3/						
Up to 150 mm (to 6 in.)	700	7 Comp, 7 EP	8 Comp, 8 EP	700	7 Comp, 7EP	8 Comp, 8 EP
Over 150 mm to 300 mm (6 to 12 in.)	450	7 Comp, 7 EP	8 Comp, 8 EP	450	7 Comp, 7 EP	7 Comp, 7 EP
Over 300 mm to 450 mm (12 to 18 in)	300	7 Comp, 7 EP	8 Comp, 8 EP	300	7 Comp, 7 EP	7 Comp, 7 EP
Over 450 mm to 600 mm (18 to 24 in.)	250	7 Comp, 7 EP	8 Comp, 8 EP	250	7 Comp, 7 EP	7 Comp, 7 EP
Over 600 mm (over 24 in.)	200	7 Comp, 7 EP	8 Comp, 8 EP	200	7 Comp, 7 EP	7 Comp, 7 EP
Double-Enveloping worm 3/						
Up to 150 mm (to 6 in.)	700	8 Comp	8A Comp	700	8 Comp	8 Comp
Over 150 mm to 300 mm (6 to 12 in.)	450	8 Comp	8A Comp	450	8 Comp	8 Comp
Over 300 mm to 450 mm (12 to 18 in)	300	8 Comp	8A Comp	300	8 Comp	8 Comp
Over 450 mm to 600 mm (18 to 24 in.)	250	8 Comp	8A Comp	250	8 Comp	8 Comp
Over 600 mm (over 24 in.)	200	8 Comp	8A Comp	200	8 Comp	8 Comp

1/ Both EP and compounded oils are considered suitable for cylindrical worm gear service. Equivalent grades of both are listed in the table. For double-enveloping worm gearing, EP oils in the correspondence viscosity grades may be substituted only where deemed necessary by the worm gear manufacturer.
2/ Pour point of the oil used should be less than the minimum ambient temperature expected. Consult gear manufacturer on lube recommendations for ambient temperatures below -10 °C (approximately 154 °F).
3/ Center distances in inches and temperature ranges in degrees Fahrenheit are approximations of millimeters and degree Celsius shown.
4/ Worm gears of either type operating at speeds above 2,400 rpm or 10 m/sec (2,000 fpm) rubbing speed may require force-feed lubrication. In general, a lubricant of lower viscosity then recommended in the above table will be used with a force-feed system.
5/ Worm gear drives may also operate satisfactorily using other types of oils. Such oils should be used, however, only upon approval by the manufacturer.

Form Standard AGMA 250.04 Lubrication of Industrial Enclosed Gear Drives, American Gear Manufacturers Association, Arlington, VA, 1974.

Table E4

Viscosity ranges for AGMA open gear lubricants

R & O gear oils (AGMA lubricant no.)	Viscosity ranges [SSU at 100 °F (cSt at 37.8 °C)]	(AGMA lubricant no.)	Residual compounds (AGMA lubricant no.) 1/	Viscosity ranges [SSU at 210 °F (cSt at 98.9 °C) 1/]
4	626 to 765 (140 to 170)	4 EP	14R	2,000 to 4,000 (428.5 to 856.0)
5	918 to 1,122 (200 to 250)	5 EP	15R	4,000 to 8,000 (857.0 to 1714.0)
6	1,335 to 1,632 (300 to 360)	6 EP		
7	1,919 to 2,346 (420 to 500)	7 EP		
8	2,837 to 3,467 (650 to 800)	8 EP		
9	6,260 to 7,650 (1400 to 1700)	9 EP		
10	13,350 to 16,320 (3000 to 3600)	10 EP		
11	19,190 to 23,460 (4200 to 5200)	11 EP		
12	28,370 to 34,670 (6300 to 7700)	12 EP		
13	850 to 1,000 (190 to 220) at 210 °F (at 98.9 °C) 2/	13 EP		

1/ Residual compounds-diluent type, commonly known as solvent cutbacks, are heavy-bodied oils containing a volatile, nonflammable diluent for ease of application. The diluent evaporates leaving a thick film of lubricant on the gear teeth. Viscosities listed are for the base compound without diluent. Caution: these lubricants may require special handling and storage procedures. Diluents can be toxic or irritating to the skin. Consult lubricant supplier's instructions.
2/ Viscosities of AGMA lubricant numbers, 13 and above are specified at 210 °F (98.9 °C) as measurement of Saybolt viscosities of *these heavy lubricants at 100 °F (37.9 °C) would not be practical.*

From Standard AGMA 251.02, Lubrication of Industrial Open Gearing, American Gear Manufacturers Association, Arlington, VA, November 1974.

Table E5

Recommended AGMA lubricants (for continuous methods of application)

Ambient temperature in degrees Fahrenheit (Celsius) 1/	Character of operation	Pitch line velocity				
		Pressure lubrication		Splash lubrication		Idler lubrication
		Under 1000 ft/min (5 m/sec)	Over 100 ft/min (5 m/sec)	Under 1000 ft/min (5 m/sec)	1000 to 2000 ft/min (10 m/sec)	Up to 300 ft/min (1.5 m/sec)
15 to 60 2/ (-9 to 16)	Continuous	5 or 5 EP	4 or 4 EP	5 or 5 EP	4 or 4 EP	8 - 9 8 EP - 9 EP
	Reversing or frequent 'start-stop'	5 or 5 EP	4 or 4 EP	7 or 7 EP	6 or 6 EP	8 - 9 8 EP - 9 EP
50 to 125 2/ (10 to 52)	Continuous	7 or 7 EP	6 or 6 EP	7 or 7 EP	6 or 6 EP	11 or 11 EP
	reversing or frequent 'start-stop'	7 or 7 EP	6 or 6 EP	9 - 10 3/ 9 EP - 10 EP	8 - 9 4/ 8 EP - 9 EP	11 or 11 EP

NOTE: AGMA viscosity number recommendations listed above refer to gear lubricants shown in Table 5. Although both R&O and EP oils are listed, the EP is preferred.

1/ Temperature in vicinity of the operating gears.
2/ When ambient temperatures approach the lower end of the given range, lubrication systems must be equipped with suitable heating units for proper circulation of lubricant and prevention of channeling. Check with lubricant and pump suppliers.
3/ When ambient temperature remains between 90 and 125 °F (32 and 52 °C) at all times use 10 or 10 EP.
4/ When ambient temperature remains between 90 and 125 °F (32 and 52 °C) at all times use 9 or 9 EP.

Table E6

Recommended AGMA lubricants (for intermittent methods of application limited to 1500 ft/min (8 m/sec) pitch line velocity 1/

Ambient temperature in degrees Fahrenheit (Celsius) 2/	Mechanical spray systems 3/		Gravity feed for forced drop method using EP lubricant
	EP lubricant	Residual compound 4/	
15 to 60 (-9 to 16)	-	14R	-
40 to 100 (4 to 38)	12 EP	15R	12 EP
70 to 125 (21 to 52)	13 EP	15R	13 EP

NOTE: AGMA viscosity number recommendations listed above refer to gear oils shown in Appendix 4.

1/ Feeder must be capable of handling lubricant selected.
2/ Ambient temperature is temperature in vicinity of the gears.
3/ Greases are sometimes used in mechanical spray system to lubricate open gearing. A general purpose EP grease of number 1 consistency (NGL1) is preferred. Consult gear manufacturers and spray system manufacture before proceeding.
4/ Diluents must be used to facilitate flow through applicators.

From Standard AGMA 251.02, Lubriction of Industrial Open Gearing, American Gear Manufacturers Association, Arlington, VA, November 1974.